32039

National Library of Canada
Bibliothèque nationale du Canada

CANADIAN THESES ON MICROFICHE

THÈSES CANADIENNES SUR MICROFICHE

NAME OF AUTHOR/*NOM DE L'AUTEUR* NAGY, GEORGE PHILIP

TITLE OF THESIS/*TITRE DE LA THÈSE* CONSTRUCT VALIDITY OF COGNITIVE STRUCTURES: A MULTIDIMENSIONAL ANALYSIS

UNIVERSITY/*UNIVERSITÉ* ALBERTA

DEGREE FOR WHICH THESIS WAS PRESENTED/ *GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* Ph. D.

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1977

NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* DR. HEIDI KASS

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

DATED/*DATÉ* April 25/77 SIGNED/*SIGNÉ* Philip Nagy

PERMANENT ADDRESS/*RÉSIDENCE FIXE*
10807 72 AVE
EDMONTON ALTA
T6E 1A4.

NL-91 (3-74)

National Library of Canada

Cataloguing Branch
Canadian Theses Division

Ottawa, Canada
K1A 0N4

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

Bibliothèque nationale du Canada

Direction du catalogage
Division des thèses canadiennes

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

NL-339 (3/77)

THE UNIVERSITY OF ALBERTA

CONSTRUCT VALIDITY OF COGNITIVE STRUCTURES: A MULTIDIMENSIONAL ANALYSIS

by

© George Philip Nagy

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF SECONDARY EDUCATION

EDMONTON, ALBERTA
SPRING, 1977

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Construct Validity of Cognitive Structures: a Multidimensional Analysis, submitted by George Philip Nagy in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

H. Kass
Supervisor
Allen T. Pearson
S. Hunka
M. A. Nay
Stanley J. Rule
W. Boldt
External Examiner

April 21, 1972
Date

ABSTRACT

This study examined the construct validity of cognitive structures, defined as sets of relationships among concepts. The investigation proceeded by multidimensional scaling analysis of concept similarity data obtained from 78 grade nine science and 54 grade 12 biology students. Using a set of 15 syntactical concepts from the domain of the scientific method (e.g., "conclusion" or "hypothesis"), subjects responded to three concept rating tests: a word association test (constrained to "scientific meanings"), a similarity judgment test, and a semantic differential test. Data were also gathered on the subjects in the form of tests of developmental level, field independence-dependence (Hidden Figures Test), and cognitive complexity.

Validity was investigated through the scaling technique of Kruskal applied to group average data, and through subgroup formation based upon individual differences in similarity judgments as revealed by Tucker and Messick points-of-view analysis and Carroll and Chang individual differences analysis. The measure of convergence of scaling solutions was a non-metric version of the orthogonal Procrustes rotation.

It was hypothesized that individual differences in cognitive structures would be linked to individual differences in personality variables. In addition to the

three tests of personality variables administered, other variables investigated included age, sex, grade, achievement, I.Q., and several variables relating to personal consistency of response on the similarity measures and fluency of response on the word association test.

All configurations reported are in three dimensions. The goodness-of-fit, taken as evidence of convergent validity, was quite high between the group average data of both grades for the word association test and the similarity judgment test (average r=0.90). Goodness-of-fit was considerably lower (average r=0.67) for the semantic differential data. Both the Tucker and Messick technique and the Carroll and Chang technique produced subgroups with interpretable configurations, indicating evidence for the construct validity of cognitive structure. Measures of goodness-of-fit between these subgroup solutions were moderate (average r=0.67), indicating some evidence for individual differences in cognitive structures. Subgroups formed by the two scaling techniques bore no relationship to each other, but subgroups formed on different similarity measures using the Carroll and Chang method bore strong resemblances to each other. Interpretability of subgroup configurations produced by the Kruskal technique was low, possibly due to high error in the data. The Carroll and Chang technique, however, produced interpretable results, and thus was judged relatively robust with respect to error.

The study provided some construct validity for the

interpretation of configurations as cognitive structures based upon data obtained by word association and similarity judgment. Individual differences in cognitive structure were found in the configurations of the subgroups formed.

None of the personality variables examined was fruitful in identifying members of subgroups formed. With the exception of the cognitive complexity test, reliabilities of the personality variables were satisfactory, with estimates by various methods ranging from 0.50 to 0.76. There was some consistency of subgroup membership within the subgroups formed by the Carroll and Chang analysis, but not among those formed by the Tucker and Messick analysis on the different data sets. It is suggested that further progress in the field depends upon refinement of the input to the scaling techniques, rather than refinement of the techniques themselves. Conceptual and empirical clarification of relevant personality variables is also a priority.

ACKNOWLEDGEMENTS

I would like to thank the members of my committee, Drs. Steve Hunka, Marshall Nay, Allen Pearson, and Stan Rule, and the external examiner Dr. Walter Boldt of the University of British Columbia for their helpful comments and suggestions during the course of the study. The staff of the Division of Educational Research Services, especially Dr. Tom Maguire, Craig Montgomerie, and Colin Park, offered programming assistance and useful suggestions.

The research would not have been possible without the cooperation of the participating classroom teachers: Cliff Adams, Marty Bodnar, Pete Harris, Dick Johnson, Cheryle Kachman, Nick Krysowaty, Gary Pho, Reg Roberts, Ainsley Sankerelli, Joyce Walton, and Pat Wright. All research was carried out in the schools of the Edmonton Public School Board.

Thanks are also due to Agnes Choy for the labourious keypunching, and to my wife Anne for the bulk of the hand scoring.

In particular, I would like to acknowledge Dr. Heidi Kass for her much appreciated assistance and encouragement, and especially for time devoted to the study during her sabbatical leave.

TABLE OF CONTENTS

CHAPTER PAGE

1. INTRODUCTION 1

1.1 Introduction 1

1.2 Purpose and Overview 1

1.3 Statement of the Problem 7

1.4 Significance of the Study 7

1.5 Clarifications and Definitions 13

1.51 Concept 13

1.52 The Nature of Structure 14

1.53 Cognitive Structure 16

1.54 Construct Validity 17

1.6 Procedure 19

1.7 Hypotheses 20

1.8 Summary 21

2. REVIEW OF RELATED LITERATURE 22

2.1 Introduction 22

2.2 Concept Relationship Research 22

2.3 Multidimensional Scaling 40

2.4 Similarity Rating Tasks 50

2.41 Constrained Association Test 50

2.42 Similarity Judgment Test 54

2.43 Semantic Differential Test 54

2.5 Personality Variables 57
2.51 Developmental Level Test 58
2.52 Field Independence-Dependence Test 63
2.53 Cognitive Complexity Test 67
2.6 Summary 70

3. PROCEDURES AND ADMINISTRATION 71
3.1 Introduction 71
3.2 Instrument Development 71
3.21 Constrained Association Test 71
3.22 Similarity Judgment Test 74
3.23 Semantic Differential Test 76
3.24 Developmental Level Test 77
3.25 Field Dependence Test 79
3.26 Cognitive Complexity Test 80
3.27 Generated Variables 81
3.3 Instrument Reliability 82
3.31 Constrained Association Test 82
3.32 Similarity Judgment Test 83
3.33 Semantic Differential Test 84
3.34 Consistency on Similarity Ratings 86
3.35 Developmental Level Test 86
3.36 Field Dependence Test 87
3.37 Cognitive Complexity Test 87
3.4 Sample and Design 88
3.5 Scoring Procedures 93
3.51 Constrained Association Test 93

3.52 Similarity Judgment Test 95

3.53 Semantic Differential Test 95

3.54 Developmental Level Test 95

3.55 Field Dependence Test 97

3.56 Cognitive Complexity Test 97

3.57 Expurgation of Data 98

3.6 Analytic Procedures 98

3.7 Summary 104

4. RESULTS AND DISCUSSION 105

4.1 Introduction 105

4.2 The Goodness-of-fit Measure 106

4.3 Reliability of Instruments 112

4.4 Group Average Results 116

4.5 Tucker Scaling Results-Cognitive Structure ... 131

4.6 Tucker Scaling Results-Personality Variables . 140

4.7 Carroll Scaling Results-Cognitive Structures . 145

4.8 Carroll Scaling Results-Personality Variables 155

4.9 Summary 163

5. SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS 166

5.1 Introduction 166

5.2 Summary of Study 166

5.3 Educational Implications 169

5.4 Recommendations for Further Research 175

BIBLIOGRAPHY 183

APPENDIX A 193

APPENDIX B 206

LIST OF TABLES

TABLE PAGE

I. Summary of Sample Attrition 92

II. Summary of Short Forms used in Tables 107

III. Relation between Goodness-of-fit Function and Correlation Coefficient 109

IV. Summary of Reliability Estimates 113

V. Stress 1 Values for Full Group Kruskal Average Solutions 118

VI. Kruskal Solutions for Full Group Average Data Three Dimensions-Rotated to a Common Target 121

VII. Summary of Interpretations for Kruskal Solutions of Full Group Data 124

VIII. Goodness-of-fit Measures for Kruskal Solutions of Full Group Average Data 129

IX. Unrotated Tucker Factoring-Percentage Total Variance Acconted for by first Nine Factors for Each Data Set Separately 133

X. Summary of Tucker Group Membership 135

XI. Stress 1 Values for Kruskal Solutions of Tucker Subgroup Average Matrices 137

XII. Goodness-of-fit among Tucker Subgroup Solutions and with Respective Full Group Solutions 139

XIII. Analysis of Variance-Personality Variables among Tucker Subgroups 141

XIV. Relations among Carroll Solutions, Kruskal Solutions, and Data for Full Groups 146

XV. Carroll Subgroup Membership 150

XVI. Stress 1 Values for Kruskal Solutions of Carroll Subgroup Average Matrices 153

XVII. Goodness-of-fit among Kruskal Solutions of Carroll Subgroups and with Respective Full Group Kruskal Solutions 154

XVIII. Analysis of Variance-Personality Variables among Carroll Subgroups 156

XIX. Summary of Interpretations for Carroll Solutions of Carroll Subgroup Data 158

XX. Summary of Interpretations for Carroll Solutions of Tucker Subgroup Data 159

XXI. Goodness-of-fit Measures among the Carroll Solutions of Full Groups and Carroll Subgroups . 161

XXII. Goodness-of-fit Measures among the Carroll Solutions of Full Groups and Tucker Subgroups 162

XXIII. Unrotated Loadings of Subjects on Principal Vectors for Tucker Solutions-Constrained Association Unscaled, Grade 9 207

XXIV. as above, for Constrained Association Unscaled Grade 12 209

XXV. as above, for Constrained Association Scaled Grade 9 211

XXVI. as above, for Constrained Association Scaled
Grade 12 213
XXVII. as above, for Similarity Judgment Grade 9 215
XXVIII. as above, for Similarity Judgment Grade 12 .. 217
XXIX. as above, for Semantic Differential Grade 9 ... 219
XXX. as above, for Semantic Differential Grade 12 ... 221
XXXI. Varimax Rotations of Loadings of Subjects on
Principal Vectors for Tucker Solutions
Constrained Association Unscaled, Grade 9 223
XXXII. as above, for Constrained Association Unscaled
Grade 12 225
XXXIII. as above, for Constrained Association Scaled
Grade 9 227
XXXIV. as above, for Constrained Association Scaled
Grade 12 229
XXXV. as above, for Similarity Judgment Grade 9 231
XXXVI. as above, for Similarity Judgment Grade 12 ... 233
XXXVII. as above, for Semantic Differential Grade 9 . 235

XXXVIII. as above, for Semantic Differential
Grade 12 237
XXXIX. Kruskal Solutions of Tucker Subgroups Rotated
to Respective Full Group Solutions 239
XL. Loadings of Subjects on Dimensions for Carroll
Solutions of Full Groups-Constrained Association
Unscaled, Grade 9 245
XLI. as above, for Constrained Association Unscaled

Grade 12 247
XLII.as above, for Constrained Association Scaled
Grade 9 249
XLIII.as above, for Constrained Association Scaled
Grade 12 251
XLIV.as above, for Similarity Judgment Grade 9 253
XLV.as above, for Similarity Judgment Grade 12 255
XLVI.as above, for Semantic Differential Grade 9 ... 257
XLVII.as above, for Semantic Differential Grade 12 . 259
XLVIII.Kruskal Solutions for the Carroll Subgroups . 261
XLIX.Carroll Solutions for the Carroll Subgroups ... 265
L.Carroll Solutions for the Tucker Subgroups 269

LIST OF FIGURES

FIGURE PAGE

1. The Nations Example 46
2. The Colourblind Example 48
3. Graphical Interpretation of Goodness-of-fit Function 110

CHAPTER 1

INTRODUCTION

1.1 Introduction

Chapter 1 presents an outline of the study. It includes a discussion of the purpose and significance of the study, a statement of the specific problem to be addressed, clarifications and definitions of terms, a brief summary of the procedure employed, and a statement of testable hypotheses.

1.2 Purpose and Overview

The purpose of this investigation was to assess the validity of three methods of uncovering cognitive structure which may describe certain interrelations among a set of science concepts. Campbell and Fiske (1959) maintain that evidence for construct validity of a method or instrument is provided when different instruments presumed to independently measure the same construct converge to the same result (convergent validity), and instruments hypothesized to be measuring different constructs discriminate between these constructs by yielding different results (discriminant validity). The nature of the term independent will be discussed below. Convergent validity of the instrument used to determine cognitive structures was assessed through the sets of relationships perceived by the same groups of people on different similarity rating tasks analysed by the same method, and the sets of relationships produced by the same groups of people on the same similarity task analysed by different methods. Discriminant validity of the cognitive structures was indirectly assessed through the sets of relationships perceived by different groups of people using the same similarity rating tasks analysed by the same method. All comparisons of cognitive structures were done through goodness-of-fit measures between multidimensional configurations of concepts hypothesized to represent the cognitive structures. Interpretations of differences in the sets of relationships were attempted by relating differences among concept perceptions to differences among groups on the personality variables studied. The construct validation may be viewed as a two step process. The first step validates the methods of gathering similarity ratings. This may be attacked through analysis of full group average data across the different similarity rating instruments. The second step is a validation of the structure itself, in the sense of showing that, in some sense, the recovered scaling solutions represent some psychological reality for the subject. This problem is attacked through analysis of the personality variables and the structures uncovered for subgroups of the sample. These personality variables include developmental level, field independence, and cognitive complexity.

Cognitive structure is viewed as an organization within a subject's memory of a set of concepts. The organization is governed by the perceived relationships among the concepts. The existence of cognitive structure is inferred from evidence gathered from the subject concerning his perceptions of the concepts and the relationships among them. This study focuses upon a set of 15 syntactical (as opposed to substantive) concepts within the domain of the scientific method (for example, "hypothesis" or "conclusion" as opposed to "energy" or "atom"). Data on perceived concept relationships were obtained from subjects by means of the methods of constrained association (Garskof and Houston, 1963), similarity judgment (Torgerson, 1958), and semantic differential (Osgood _et al,_ 1957). Information obtained from subjects was processed by multidimensional scaling techniques (to be described in detail below) to yield configurations of the concepts represented as points in geometrical space, with distances between points corresponding to perceived dissimilarities among concepts. Besides the validity of cognitive structures, this study also addresses (although indirectly) the validity of representing these structures geometrically. Inferences are drawn from the multidimensional configurations to the organization of the concepts within the subjects' memories. Similarity of configurations obtained from analyses of data from the same subjects by different experimental techniques is taken as evidence that the tests are tapping the same internal cognitive structure. Because of the nature of the data, configurations based upon group averages rather than individual data must be calculated. Averaging is necessary to allow random errors in individual data to cancel, producing data with less error and facilitating interpretation of the derived configurations. Since generalization to the perceptions of individuals is desired, the necessity of using grouped data imposes a limitation to the techniques used. Only by averaging and allowing some random error to cancel can the techniques produce interpretable results.

The term constrained is used in several senses by different authors whose work is reported here. With reference to word association tests, the term constrained has been used to mean any of the following: "respond with words you would use to define the stimulus word"; "produce exactly five responses"; or "respond with physics words only". In the present study, the term constrained was taken to mean "respond while thinking of the scientific meaning of the stimulus word".

The constrained association task yielded a set of relatedness indices that were used as similarity measures for further analysis. The similarity judgment technique yielded a measure of similarity directly with no additional data manipulation. The semantic differential results were analysed by first producing an intercorrelation matrix for the ratings of the concepts based upon the patterns of responses produced, and then using these intercorrelations as measures of similarity.

Data gathered by the above methods were examined as follows. First, grouping the subjects by grade only (grades 9 and 12 were used), the group average data for each grade were subjected to multidimensional scaling analysis (hereafter known as Kruskal scaling) (Kruskal, 1964a, 1964b) to estimate the overall dimensionality of the cognitive structure of the entire grade group. Second, based upon the estimate of dimensionality obtained from the Kruskal analysis, the similarity matrix data were subjected to both points of view analysis (Tucker and Messick, 1963; Jackson and Messick, 1963) and individual differences analysis (Carroll and Chang, 1970; Carroll, 1972). These methods will be referred to as Tucker scaling and Carroll scaling, respectively. Kruskal analysis itself is not one of the methods under investigation. Preliminary investigation of dimensionality by this method was done for purposes of comparison of the group average results on the several data sets, and as a computer cost reducing device, since assessment of dimensionality by the Tucker or Carroll techniques is very costly.

Kruskal scaling analysis has as its goal the uncovering of underlying dimensions that can be used to express geometrically the relationships among the data points under investigation. The Kruskal method is based upon group or average data. The Tucker and Carroll analyses have similar goals, with added facility to manipulate individual rather than group data. This facility allows the uncovering of differences among subjects in their perceptions of the relationships among the data points under investigation. The Tucker method uses an obverse principal components analysis of the similarity ratings by subjects matrix in order to characterize subject types according to their loadings on the factors produced. Kruskal analyses of the data produced by each of these types can then be compared. The Carroll analysis operates on a three dimensional array consisting of the similarity rating matrices obtained for each subject to produce a mapping of concepts into a geometrical space of any chosen number of dimensions, along with a subjects by dimensions set of weights that estimate the salience or importance of each of these dimensions to each subject in his individual estimates of concept similarity.

The Tucker method and the Carroll method have as their goal the revealing of individual differences in matrices of similarity data. If the data meet the assumptions underlying both techniques the results should be comparable. Subgroups of subjects can be formed on the basis of the results of either analysis. Commonality of subgroup membership based upon each analysis may be taken as evidence of the applicability of both techniques to the data. However, lack of such commonality cannot, within the limits of the analyses undertaken herein, be used to show the inapplicability of either method to the data.

1.3 Statement of the Problem

This study was an investigation of perceived similarities among a set of 15 syntactical concepts from the domain of the scientific method. The same subjects were asked to respond in three different judgmental tasks to the same set of concepts. The questions addressed by this study are:

(1) Are there commonalities among the configurations uncovered for entire groups of subjects by the three techniques?

(2) Are there differences among subgroups in the configurations uncovered by either of the techniques which apply to individual data?

(3) Can these differences be related in a meaningful manner to personality variables measured independently of the similarity rating tasks?

1.4 Significance of the Study

The present study ascertains the degree of relationship among students' cognitive structures in the domain of syntactical science concepts as indicated by three judgmental tasks. According to Campbell and Fiske (1959) construct validity of instruments must be demonstrated by both convergent and discriminant validation processes. First, construct validity of a hypothetical construct in a given domain (cognitive structure) will be enhanced if the construct can be measured by experimentally independent means and if these independent measures of the construct correlate positively and significantly with each other. Second, construct validity is further enhanced if the measures of the construct correlate relatively poorly with measures of other constructs. The argument for convergent validity is straightforward, but that for discriminant validity is open to question.

With respect to convergent validity, high correlation between tests which purport to measure the same construct may be taken as evidence of construct validity only if it can be established that the tests are independent of each other. That is, it must be established that the correlation between the tests is not an artifact of, for example, a common testing format, a common testing time, or some other extraneous variable. The meaning of independent, as used by Campbell and Fiske, must be made explicit. Clearly, two tests measuring in the same domain would have enough in common that too stringent an interpretation of the term independent would make convergent validity impossible. It is difficult to imagine tests aiming at the same construct but being completely unique in goals, methods, and assumptions. In the present context, the three tests used to obtain similarity information may be argued to be independent in a manner appropriate to the Campbell and Fiske usage. All three deal with syntactical concepts in the domain of science, and are thus related. However, only in one of the tests, the similarity judgment test, would a naive subject even be aware that similarity information was being elicited. For the word association and semantic differential tests, the subject is asked to consider only one of the 15 concepts at a time. Further, in two of the tests, the similarity judgment and semantic differential, judgments are required, but in the case of the semantic differential, the subject is asked to relate one concept under study to adjectival pairs describing it, while in the similarity judgment test, he is asked to relate two of the concepts under study. In the word association test, the subject is asked to associate to a concept word. It is hoped that the concepts presented will set the context enough that the subject would be operating in the scientific context rather than, for example, the legal (cf., "law" or "evidence") context. Word association tests come from a psychoanalytic tradition, similarity judgment from a psychophysical tradition, and semantic differential from a linguistic tradition. The three tests are similar enough to be within the same domain but different enough to qualify as independent for purposes of convergent validity.

Campbell and Fiske's argument for discriminant validity has been criticised by Cronbach (1971). Cronbach maintained that it is not necessary for a pair of constructs to have low correlations between them in order that each be worth support as a scientific explanatory device. He argued that any correlation substantially below 1.00 is sufficient to allow the possibility that both of two related constructs may be scientifically useful. This discussion of discriminant validity is not central to the present study in that, as will be discussed in detail below, it is not clear what would constitute establishment of discriminant validity of cognitive structure.

The psychological significance of the study lies in its potential for establishing the construct validity of a view of cognitive structure as evidenced by a set of interrelations among concepts mapped onto a geometric space. Such validity can only help to bring conceptual and definitional clarity to the idea of cognitive structure, which appears in the literature in confusing and competing contexts (Ausubel, 1965; Bruner, 1960; Schwab, 1974.).

The educational significance of the study pertains to the example concepts chosen for study. The concepts are:

Conclusion
Discovery
Evidence
Experiment
Explanation
Fact
Hypothesis
Imagination
Interpretation
Investigation
Law
Proof
Puzzle
Question
Theory

The particular concept domain investigated, that of syntactical concepts of the scientific method, has been chosen because of: (a) its applicability across the grade levels in question (grades 9 and 12), thus allowing assessment of some developmental aspects of cognitive structure; the ease with which dimensions of the concept domain may be interpreted relative to other concept domains that have been investigated by similar methods (Kass, 1971; Shavelson, 1972); and (c), the interest that the structure of scientific method itself has generated (Kuhn, 1962; Braithwaite, 1973).

The cognitive structure of a student regarding scientific method has potential as both an independent and dependent variable in curriculum evaluation and design. It may be possible to judge the relationship of specific student characteristics, such as I.Q., developmental level, or cognitive style to the cognitive structure among the above elements uncovered for that student. Although the educational import of this study lies principally in the application of the methodology to other, perhaps educationally more central concepts, further research with these concepts may reveal curricular consequences for the teaching of science. It may be possible to enhance the teaching of science by matching instruction to students' perceptions of the interrelationships among syntactical elements of science. Such a possibility is in line with Hunt's (1971) recommendation to match instruction to student characteristics. It may further be possible to design instruction to change a student's perception of the relationships among aspects of the scientific process. Research investigating the relationships among cognitive structure, instruction, and achievement is reported in detail below (Johnson, 1964, 1965, 1967; Shavelson, 1972, 1973, 1974).

The study has psychometric consequences in that it investigates a methodology for the uncovering of cognitive structure that has potential applicability to any set of related concepts, syntactical or substantive, within any domain of interest.

This study is limited in that, although there is no logical reason for supposing a lack of connection between cognitive structure and science achievement, the cognitive structure among the particular concepts studied cannot be predicted with any confidence to be a significant intervening variable for achievement in any common high school science course. Evidence has shown (Aikenhead, 1972; Simpson et al, 1972; MacDonald, 1974) little relationship between understanding the processes of science, however defined, and science achievement. Thus, unlike those studies which dealt with the structure within substantive concepts (Kass, 1971; Shavelson, 1972), no direct link with subject matter achievement can be expected from this study of syntactical concepts. However, this limitation is balanced by the advantage that these concepts, since they are not directly bound up in immediate classroom learning, may exhibit more individual variation in perception than would be expected from a set of concepts taken directly from recent or ongoing instruction.

1.5 Clarifications and Definitions

1.51 Concept

Carroll (1964) defines concepts as "properties of...abstracted and often cognitively structured classes of 'mental' experience." Experience in turn is defined as "any internal or perceptual response to stimulation". The term abstracted is the key to Carroll's definition of concept. Concepts are abstracted from a set of experienced exemplars. A necessary step in the formation of a concept is a differentiation of a subset of experience (exemplars of the concept) from the entire set of experience (both exemplars and non-exemplars of the concept). This generalization produces a very limited concept. A concept is further developed through its relations with other concepts. For example, the concept "stool" may be closely identified with the concept "chair", with the exception of the relational property "without a back". The concept "chair" in turn may be related to the more subsuming concept "furniture" by the relational property "for sitting on". The set of relationships among concepts is defined as cognitive structure.

For purposes of this study, a concept was delimited in terms of an educational concept rather than a laboratory concept. For Carroll, such a distinction is between a student learning the concept longitude and the concept of learning to associate the nonsense syllable "DAX" as the name of a geometric shape of a certain colour. The concern of this study is entirely with educational concepts.

1.52 The Nature of Structure

This section will address the problem of defining the status of cognitive structure. The discussion will not focus on whether or not structure is best defined as hypothesis, theory, or model. Such a discussion would not prove worthwhile in that it would necessarily involve semantic arguments concerning the definitions of practically all substantive terms introduced (cf., Black, 1973). Instead, the discussion will focus on the type of role cognitive structure is likely to play in any explanation of human thinking.

First, the notion of an internal structure places the discussion squarely in the cognitivist rather than the behaviourist school of psychology. Cognitive structure has been described (Morgan, 1972) as an intervening variable which acts to form an individual's response to his environment. It is posited to be a result of experience, and to grow in the course of normal human development in organization and differentiation. Experience acts on cognitive structure both to add to it (in the sense of adding new experience) and to change it (in the sense of changing perceptions of and interrelations among old experiences). These two results of experience correspond closely to Piaget's (Inhelder and Piaget, 1958) assimilation and accommodation. According to this line of reasoning, cognitive structure relating relevant concepts should play a role in determining response to the environment, and therefore differences in cognitive structure should evidence themselves in differences in response to the environment.

The significance of a clear definition of cognitive structure to the justification of the study rests on the fact that the analytic technique of multidimensional scaling always produces a result. The problem of interpreting this result rests with the (at least partly) subjective interpretive abilities of the investigator. Cognitive structures which are the result of such interpretations may be more or less meaningless because of: (a) random error; (b) inappropriateness of the task to the age level tested; (c) inappropriateness of the assumptions of the analytic techniques to the data; and (d), inappropriate criteria for judging the reliability of the results. Any combination of the possibilities listed could lead to misinterpretation of results. Because of this possibility, the uncovered structures are best interpreted as hypotheses. Such hypotheses must pass the test of independent corroboration. This study has attempted to provide such corroboration, by endeavouring to relate differences in perception of concept relationships among groups of subjects to differences among groups on the personality variables. A major criterion for the meaningfulness of the results of the present study involves relating, in a theoretically satisfactory manner, differences in subgroups' configurations to differences in their personality variables.

1.53 Cognitive Structure

An assumption must be made in order for research on concepts to proceed. An experimenter does not have direct access to concepts, in that concepts are not observable. They must be inferred on the basis of the observable behaviour (either verbal or otherwise) of the subject. There must be an assumption that the words (in verbal behaviour) as used by one subject share some presumably connotative commonality of meaning with the same words as used by another subject. That is, the word meanings, and therefore the concepts, are shared. Such an assumption does not mean that the meanings of terms as used by individuals must be coextensive. If such were true, there would be no reason for doing research on concepts. Introspection by the researcher would do as well as research. No commonality of word meaning makes the research impossible; perfect commonality of word meaning makes the research unnecessary. Kaplan (1964) points out that the meaning of theoretical expressions is always given in terms of a theory, that is, by using other theoretical expressions. In the language of this study, a concept is defined in terms of other concepts within the same cognitive structure. A shift in a subject's meaning for a concept implies a shift in the relationships among concepts, that is, a change in the cognitive structure. Only some commonality of meaning (i.e., "ballpark commonality") is necessary for the research to proceed. From Kaplan's point of view, what we are investigating when we look at cognitive structure are the subtle shifts in meaning of concepts as perceived by different individuals.

1.54 Construct Validity

As mentioned above, the approach taken in this study fulfils one of the requirements for establishing construct validity given by Campbell and Fiske (1959) but not the other. If sets of similarity data on the same concepts gathered from the same subjects by quite different methods all indicate closely related results when analysed, this is evidence that the methods of finding similarity information converge on the same cognitive structure. Further, if a set of similarities when analysed by two different scaling techniques also converges on the same cognitive structure, this is demonstration that the convergence is not a function of the scaling method alone. In using both the above procedures, this research design conforms to the multimethod part of the Campbell and Fiske recommendations.

With respect to discriminant validity, there does not seem to be a clearcut method of establishing validity when the construct under investigation is cognitive structure. For example, it seems futile to collect data on a second set of concepts. There is no parallel between showing that, say, a test of compulsiveness correlates poorly with a test of anxiety, and showing that a second set of concepts do not produce the same set of relationships among themselves as the set of concepts under study. A possibly fruitful approach to establishing discriminant validity, and the one used in this study, involves collecting similarity data from different groups of subjects who might be hypothesized as having different cognitive structures and showing that this is indeed the case.

Unfortunately, with concepts that are intended to have some significance in the domain of public education, such as the ones chosen for this study, the subject is not totally free to produce a completely unique set of similarities. Kass (1971) found a strong tendency on the part of subjects to deviate very little from the group average in perception of a set of heavily content oriented mechanics concepts. In other words, the content structure inherent in the concepts obliterated individual differences. The subjects perceived that there were right answers. Carroll and Chang (1970), using political concepts for which there were no correct answers found good variation in perception. The concepts used in this study, while not as bound to content as those used by Kass or Shavelson (1972), are not as free to be individual as those of Carroll and Chang. Thus, multitrait validity can only be expected to appear as deviations from the "right answer" content structure, rather than as a quite unique perspective on a set of concepts. As will be seen below, the issue is even more complicated due to the lack of a statistical criterion for the measure-of-goodness of fit between structures used in this study, namely, the non-metric version of the orthogonal Procrustes rotation (Lingoes and Schonemann, 1974; Schonemann and Carroll, 1970). This technique will be referred to as the non-metric fit procedure.

1.6 Procedure

Six tests, three of concept similarity and three of personality variables, were administered to 132 subjects in grade 9 (N=78) and grade 12 (N=54). The concept similarity tests have been briefly described above. The personality tests were a test of developmental level, a test of cognitive complexity, and a test of field dependence-independence. The concept similarity tests were analysed to produce matrices of similarities, which were converted to multidimensional configurations by the scaling techniques outlined above.

Construct validity of the uncovered configurations was established primarily by examining the correspondence of the configurations to each other. The extent of correspondence was assessed by the technique of nonmetric orthogonal Procrustes rotation (the non-metric fit procedure). Graphical techniques were used to present a possible interpretation of this measure of fit.

The subjects were assigned to groups according to factor loadings obtained from the Tucker analysis, and the saliences on each dimension for the Carroll analysis. These subgroups were compared among each other and with the full group for differences in cognitive structure, and for differences in the personality variables. Personality variables examined were I.Q. (grade nine only), achievement, developmental level, analytic-synthetic cognitive style (Witkin, 1965), and cognitive complexity (Seaman and Koenig, 1974) as well as estimates of the subjects' personal consistencies on each measure, their total number of responses on the word association test, and an estimate of the individual overall reliabilities on the three measures for a given subject.

1.7 Hypotheses

The hypotheses of the study may be stated in summary form as follows:

HO(1). There will be no significant differences among the structural patterns revealed by Kruskal analysis of data based upon constrained association, similarity judgment, and semantic differential tests;

HO(2). There will be no significant difference between the structural patterns uncovered within each grade among groups formed by the sequences of:

(a) constrained association followed by Tucker analysis;

(b) constrained association followed by Carroll analysis;

(c) similarity judgment followed by Tucker analysis;

(d) similarity judgment followed by Carroll analysis;

(e) semantic differential followed by Tucker analysis;

(f) semantic differential followed by Carroll analysis. Pending the results of H0(2), there is a further hypothesis: H1(2). Differences in structural patterns as found in the groups as formed by the Tucker analysis, and again by the Carroll analysis, will be related to personality variables of the subjects.

1.8 Summary

This chapter has outlined the purpose and significance of the study. Major terms have been clarified. The problem to be addressed has been stated, a procedure for doing so has been outlined, and the problem has been put in the form of testable hypotheses.

Chapter 2 of this report summarizes literature related to the study. Chapter 3 presents details of the administration of the study, the scoring procedures, and the analytic procedures. Chapter 4 contains results and discussion, while Chapter 5 summarizes and concludes the report.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter is divided into four main sections. Section 2.2 discusses research focused on measuring concept relationships in an educational context, with particular attention to science education. Section 2.3 discusses the rationale and assumptions of the three multidimensional scaling procedures used in the study. Examples of the uses of these techniques in the literature are briefly outlined. The next section deals with the origins and uses of the three similarity rating tasks. Section 2.5 concerns the three personality variables tasks, as well as a brief mention of other personality variables generated during the course of the analysis. Of necessity, the sections of this chapter refer both back and forth to each other to a considerable extent.

2.2 Concept Relationship Research

The purpose of this section is to trace the development of attempts to measure concept relationships, primarily in science education research. Studies have been conducted on the relationship of cognitive structure to achievement, the usefulness of word association tests in the uncovering of cognitive structure, and the relationship of cognitive structure to subject matter structure. Some of the research has used scaling techniques, and some of the research has attempted to measure individual differences in cognitive structure. All of the research has suffered from conceptual flaws and/or unavailability of appropriate analytic tools.

Johnson (1964; 1965; 1967) conducted a series of studies showing the possibilities for uncovering similarity data from verbal association tests, for relating verbal output on such tests to achievement, and for relating similarity matrices produced by the above method to those produced by similarity judgment techniques. In the first study (1964) he compared the strengths of associative meanings among physics concepts for four groups of subjects (50-70 per group) with varying degrees of involvement with physics. The groups were all grade 11 and 12 girls: (1) having taken physics; (2) taking physics; (3) planning to take physics; and (4) not planning to take physics. Subjects responded with one written free association to each of a series of 18 concepts read aloud 5 seconds apart. The frequencies with which the 18 concepts were used as responses to each concept were tabulated and converted to a matrix of percentage similarity. Significant differences in the average similarity among all four groups were found in the order 2, 1, 3, 4. In the second study (1965), Johnson, using as subjects 166 female high school seniors taking physics, gave a written constrained version of the word association test along with a ten-problem physics test. Half of the sample took the tests in the reverse order from the other half. Subjects were constrained to write the first physics word which occurred to them as a response. Responses were categorized as (a) words from the concept list, and (b) "responses which occurred together with their respective stimuli in a constraint necessary for the solution of one of the ten problems." Concepts were chosen so that, for all cases, category (b) was included in category (a). Subjects who had the problem test first produced significantly more responses of both types (a) and (b). Subjects who had the association test first scored significantly higher on the problem test. The correlation between number of (a) responses and test achievement was 0.34 ($p<.05$) for the group which had the association test first, but -0.03 for the other group. For type (b) responses, the correlation was 0.42 ($p<.05$) for the association test first group, and 0.19 for the other group. Johnson also reported many results for the individual concepts. He concluded "language habits which have been learned among words in physics are an integral part of the conceptual framework a student utilizes in dealing with concepts in the subject matter".

An important limitation to the work of Johnson up to the time of his study was the fact that his analytic technique could not make use of responses common to two stimuli but not on the list of concepts to increase the degree of calculated association. Such a problem is circumvented by the Garskof and Houston (1963) method, decribed in detail below.

In a third study, Johnson (1967) used the calculation procedure of Garskof and Houston along with a similarity judgment test on fourteen physics concepts using a sample of 24 high school seniors (16 male, 8 female) divided into 12 high and 12 low achievers. The concepts were ranked according to their occurrence in subject matter presentation (presumably by a textbook word count, but this is not reported) and according to their frequency of occurrence as responses by the two groups. Rank order correlations between the orders produced by each group and that of the subject matter were 0.87 ($p<.001$) for the high group and 0.52 ($p>.05$) for the low group. When the order of occurrence for each concept response within the response list produced was taken into account, the respective correlations became 0.52 ($p>.05$) and -0.05 ($p>.05$). Johnson defined a constrained association (in a manner not to be confused with the use of the term in this report) as a relation constrained by a law of physics. For example, "force", "mass", and "acceleration" are constrained responses to each other because of the physical law "force = mass x acceleration". High achievers gave significantly more constrained associations than low achievers, both considering and not considering order of response. After calculating Garskof and Houston relatedness indices for both groups, and similarity judgment indices based upon that part of the experiment, Johnson reported a rank order correlation between the two of 0.75 (p<.001) for the high group and 0.65 (p<.001) for the low group. The significance of Johnson's work for the present study lies in the estimation of the magnitude of the correlation between the similarities gathered by the two techniques.

In a follow up study, Johnson, Curran and Cox (1971) gave a free association test, a constrained association test, and a similarity rating test to a group of 49 male physics majors who had completed at least three years of college. The nature of the constraint on the constrained association test was that subjects were asked to list the words they would use in defining the stimulus word. The authors report good correspondence for both the free and constrained association tests with their hypothesized degree of relationship among the nine stimulus concepts. Of more interest here are the rank order correlations among the indices of relationship produced by the three methods. These are: free and constrained association, 0.90; free association and similarity judgment, 0.85; and constrained association and similarity judgment, 0.79. These results lend credence to the expectation that correspondence among the various methods should be expected in the present study. Such correspondences probably should not be as large as Johnson's results because of the highly homogeneous nature of the subjects he used compared with those in the present study.

Reporting further analysis of what appears to be the same data, but using only six of the concepts, Johnson, Cox, and Curran (1970) performed a Kruskal scaling on the six points using the free association data and the similarity rating data. Relatedness indices were calculated as in Johnson's earlier work rather than by the Garskof and Houston method. Despite citing Klahr's (1969) caution against using such a small number of points in a scaling analysis, Johnson et al reported solutions in two and three dimensions. Although they achieved zero stress in three dimensions, they admit that there is a possibility of such an occurrence by chance. Scaling of such a small number of points appears to be a misuse of the Kruskal technique.

Evanechko and Maguire (1972) have studied the dimensionality of children's meaning space. Although this study was not related to science education, it is included in this review because of the comparability of both the techniques and the ages of the subjects to the present study. A Semantic Features Test was developed to investigate the types of definitions preferred by children. Evanechko and Maguire produced a list of 24 ways of perceiving meaning between words. Examples are: synonym, attribute, whole-part, generic definition, etc. Each of the 24 categories was used to prepare 23 example pairs of the particular definitional or meaning relationship. For example, under "whole-part" were bird-wing, hand-finger, and 21 others. Using this technique, it was possible to produce 276 possible pairs of the 24 categories without repeating the actual examples. The subjects were presented with the 276 pairs of pairs and asked to decide which pair constituted the better definition of the first word in each pair by the second. The directions given the subjects were to "think of the kind of meaning given for each word and choose the one which is nearer to what you think the word means in each pair of statements".

The sample consisted of 266 students in the fifth and eighth grades. A group average proportion of times one meaning category was preferred over another was calculated for the pairs of categories, producing a 24 x 24 matrix of proportions of preference. These values were deviated around 0.50, and the absolute values taken to produce a matrix of dissimilarities. This matrix was scaled by the Kruskal technique. Four dimensional solutions for each grade were reported, with stress 1 (variance unaccounted for) close to 16 percent in both cases. For purposes of interpretation, the 24 categories of meaning were grouped into five larger categories. Reasonable interpretations of the four dimensions were given for both grade levels. An orthogonal Procrustes rotation (Schonemann, 1966) of the grade eight solution to the grade five solution indicated a poor fit. Since the metric version of the rotation was used, the conclusion presented by Evanechko and Maguire that the two solutions are substantially different must be doubted.

Kruskal analysis is a technique designed to apply to ordinal data. The orthogonal Procrustes rotation, designed for at least interval data, is not appropriate. It seems a rather large leap from the directions given to the subjects to the reporting of the results in which the terms "meaning" and "relationship" seem to be almost synonymous. Further doubt must be cast upon the results because of the taking of the absolute values of the differences between the proportions of preference and the value 0.50. By this method, the proportions 0.30 and 0.70 become identical. While the "dissimilarity" has been preserved, the "preference" has been lost. The study provides useful information about the similarity of the relationship categories as perceived by the subjects, but no information about their preferences. The significance of the Evanechko and Maguire study is that it demonstrates that, on group average data, and despite serious conceptual flaws, subjects as young as grade five will produce meaningful results on a task which is comparable in difficulty to the tasks in this study.

Kass (1971), using a sample of 353 grade 12 physics students, obtained similarity ratings on the 190 possible pairs of 20 mechanics concepts. Her concepts were described by short phrases and/or formulae rather than merely being named. Each subject was given the pairs of stimuli on 190 cards and told to rate their similarity in difficulty on a scale of 1 to 9. This technique corresponds most closely with the similarity judgment technique of the present study, except for the imposition of a definition of similarity in terms of difficulty. Such an imposition may be expected to distort the similarity judgments of the subjects, for it is possible that a subject might consider a pair of otherwise unrelated concepts as being quite similar in difficulty but in no other aspects. Kass analysed the resulting matrix of similarities by the Tucker-Messick method, but found that there were insufficient differences in individual perceptions to warrant pursuit of the individual aspects of the study. As mentioned above she suggested that the use of heavily content oriented concepts, taken directly from course content may reflect mostly the structure of the discipline, as viewed by subject matter experts, and very little of the individual perceptions of the subjects. Using group average data, three stratified (by class) random samples of 60 subjects each were compared in group average cognitive structure. Using Kruskal's stress 1 and interpretability of the loadings in terms of concept meaning as criteria, the four and five dimensional solutions were judged most satisfactory. Stress 1 values were between seven and ten percent. Comparisons of the loadings was done by the use of the Kaiser (1960) factor match test, a metric technique. The non-metric version of the orthogonal Procrustes technique was unavailable at the time. No goodness of fit measure between the structures produced by the two groups is reported. In the cases of both the four and five dimensional solutions, Kass offered reasonable explanations of the loadings of the concepts on the factors in terms of the concept meanings for three of the dimensions.

Shavelson has published a series of studies investigating the relationship between content structure as represented in instruction, and cognitive structure as represented in student memory (Shavelson, 1972, 1973, 1974; Shavelson and Stanton, 1975) In the first study, he employed a combination of grammatical analysis and digraph theory (Harary, Norman, and Cartwright, 1965) to recover a matrix of similarities among physics concepts from the students' text. Digraph (directed graph) theory is a mathematical technique in which concepts are represented by points, and the relationships among them by directed lines joining the points. Harary, Norman, and Cartwright provide a discussion of the abstract properties of the networks drawn, but do not concern themselves with the details of correlating grammatical analysis with their system. Shavelson (1972) gives some clues to the technique, using the text sentence "Force is the product of mass and acceleration" to produce a graph linking the concepts "force", "product", "mass", and "acceleration" with the relational properties "is", "of", and "and". The technique is not completely clear from one example, and Shavelson refers the reader to Shavelson (1970), which is not readily available, for further details. Some further detail is provided by Shavelson and Geeslin (1975), but not enough to allow replication of the method.

Harary, Norman, and Cartwright provide details of a method for linking digraphs containing common elements to each other, and for converting this large digraph to a matrix of dissimilarities. Shavelson analysed a physics text, and produced a digraph for each sentence of the text which contained two or more of his list of 14 mechanics concepts. Since the distance between two points in a digraph is the number of directed lines between the points, Shavelson eliminated all but those digraphs which produced the shortest path between any two concepts. He then combined digraphs and produced a matrix of subject matter dissimilarities. Shavelson interpreted this matrix as representing the content structure of the material.

Cognitive structure in the 1972 study was estimated by an unconstrained free association test using the fourteen concepts as stimuli. Relatedness indices were calculated by the Garskof and Houston method. Using a sample of 40 naive but interested high school age volunteers (28 experimental and 12 control), Shavelson measured changes in cognitive structure over five days of instruction based on the text which produced the content structure described above. A significant gain on an achievement test and an insignificant increase over time in the total number of responses provided by the subjects to the association test are reported. In addition, subjects in the experimental group had a median relatedness index which increased regularly across the six administrations of the test (an initial test and one following each day of instruction), while that of the control group remained low and stable. The control group completed all the tests of the experimental group, but spent the rest of the treatment time participating in another (unreported) study.

Shavelson produced a matrix of Euclidean distances between all pairs of relatedness index matrices. This was a six days by six days matrix of distances between relatedness index matrices. The method involves (a) subtracting the corresponding values for all relatedness indices in the two matrices, (b) squaring and summing these values, and (c), dividing by the number of entries in a matrix and taking the square root of the result. For the control group, the average distances were uniform and small over the six days, but for the experimental group, the average distance was fairly regularly related to the separation in time of the testing occasions. Shavelson did similar calculations comparing the control group and experimental group matrices on the same day. Similar results allowed him to conclude that the two groups started out with similar cognitive structures, but that that of the experimental group grew away from that of the control group.

These analyses were followed by conventional Kruskal scaling on the matrices produced by each group each day. Using the two dimensional solutions, which produced stress 1 (presumably) less than 10 percent, Shavelson could not corroborate the conclusions based upon his average distance calculations, and had to resort to rather weak explanations involving the control group having "prescientific" meanings for the concepts which corresponded quite closely to the scientific meanings. Shavelson performed his average distance comparison of the cognitive structure with the content structure revealed by the digraph analysis. This calculation showed that the experimental group grew towards the content structure, while the control group did not. Again, Kruskal analysis of these structures failed to confirm these conclusions.

Shavelson (1973) has reported further results on the same experiment. On the word association test, if only responses from the original stimulus list are counted (constrained responses, in Shavelson's terminology), then there is a significant relationship between number of responses and achievement on the achievement test, especially when the constrained response occurred early in the list of responses. Shavelson reports a significant but small relationship between achievement and the Hidden Figures Test (French *et al.* 1965), which is used in the present study. Unfortunately, he does not report the results relating the HFT to differences in cognitive structure. In a longer article (1974) which mentions the earlier results, Shavelson maintained that multidimensional scaling of a matrix of relatedness indices taps cognitive structure. As an alternative method of collecting information on cognitive structure, Shavelson suggested lexical graphing methods

(Rapoport et al , 1966). This suggestion has not been used in the present study because of the complexity of the directions needed for a subject to perform a lexical graphing. The technique has possibilities, however, for work with more mature subjects.

Shavelson's data raise a lot of questions. Preece (1976c) has responded in a note to Shavelson (1972, 1973, 1974) regarding the use of his average distance between matrices calculation. Preece demonstrated by a neat example that the technique is inappropriate, in that the value depends as much upon the average absolute value of the relatedness indices as upon any change in their relative sizes. On the basis of this criticism, and his own scaling results, Shavelson's data do not support his conclusion that cognitive structure "grows towards" content structure with instruction. The idea is intuitively appealing, however, and it would be interesting to attempt to use the goodness-of-fit measure of the nonmetric orthogonal Procrustes rotation as a measure of growth on his data. It would be a reasonable hypothesis that, as the experimental group progressed through instruction, their geometric representation of the concepts, as found by Kruskal analysis, would yield successively better measures of fit when rotated to the content structure as revealed by digraph analysis. Conversely, similar results for the control group should not yield improving goodness-of-fit measures.

Shavelson and Stanton (1975) seem to view the convergence of different methods of measuring cognitive structure on the same similarity matrix as validation for the construct "cognitive structure". The methods under discussion were: word association, card sorting, and lexical graph building. This suggestion is of relevance to the current study because of the similarity in intent and underlying assumptions of the card sort technique to the similarity judgment technique (Torgerson, 1958) as used in the present study.

Preece (1976a, 1976b) has reported two studies of interest. In the first study, he measured the relationships among 15 mechanics concepts using a sample of 28 physical science student teachers, all with degrees in science. Subjects were presented a written free association test, a controlled association test, and a tree construction test similar to the lexical graphing method of Rapoport et al (1966). In a tree construction task, subjects are presented with a list of concepts and are asked to select the two most closely related. They write this pair in the centre of a page and join them by a line. They then choose a concept from the remaining list that is most closely related to either of the concepts already chosen and add it to the page, joining it by a line to the concept it is most closely related to. The actual directions are more complex, but essentially the subject continues in this manner until the list of concepts has been exhausted. The control in the controlled association test asked subjects to list physics words as responses, and asked for exactly five responses. Preece obtained what he described as very poor relationships between the results of the association methods and the tree method. This judgment by Preece of his own data seems harsh. Preece produced six matrices of similarity from the responses of each subject. Four of these were based upon association tests and two on tree construction tests. On group average data, and multiplying by minus one where necessary to compare similarities and dissimilarities, the lowest correlation between any pair of tests was 0.8 ($p<.001$). When compared with his theoretical prediction, the lowest correlation found is 0.60 ($p<.001$).

The tree method is considered appropriate when a geometrical model will not fit the data. Such a situation would occur if the concepts grouped themselves into closely related clusters separated by relatively large distances. Under such conditions, scaling techniques would produce a degenerate solution, with large distances exaggerated and small ones attenuated. Such conditions were not a problem in either Preece's study or the present one. It is important to note that the type of association test used in the present study is closer in spirit to Preece's free association test than to his controlled association test. On the free association, Preece reports one month test-retest reliability of 0.86 using eighteen year old subjects. This reliability appears to have been based on the second study (Preece, 1976b), in which he used the Carroll scaling method on a sample of boys ages 11, 14, and 18 from a boy's grammar school. The boys responded to the same concepts as the student teachers. Details in this second report are sketchy. There evidently were individual differences among subjects, but we are given no indication of their magnitude or their nature in terms of either the subjects or the concepts.

It appears that Preece misinterpreted the plot of subjects in dimension space produced by the Carroll program. He interpreted a subject's distance from the origin as a reliability, in the sense that it measures conformity of the subject's actual dissimilarities with the subject's estimated distances. While the measure does indeed give a correlation between a subject's actual data and his estimated data, this correlation is not directly interpretable as a reliability of either the subject's responses or of the technique as applied to his data. The subject's conformity to the group average will largely determine the variance in his responses which can be accounted for by any weighted composite of the group average perception space. For interpretation of an individual's loadings in a Carroll analysis, there are two "best fit" steps. One involves fitting the group average similarity data into concept space, and the second involves fitting the individuals into subject space. The resulting distance of a subject from the origin of subject space depends upon the error in the group average data, the goodness-of-fit of the group average solution, the homogeneity of the group, the conformity of the subject to the group average, and the error in the subject's data. Direct interpretation of this distance from the origin is not recommended.

In summary, Johnson established the possibility of using word association tests to measure concept relationships. He also linked achievement to responses on association tests, and presented evidence of convergence between association tests and similarity judgment tests. Evanechko and Maguire showed that similarity judgment methods would yield reliable results with subjects even younger than those in the present study. Kass made the first attempt at finding individual differences in cognitive structure, but found that heavily content oriented concepts yielded only small variation among subjects. Shavelson, although he used methods open to criticism, attempted to measure cognitive growth in terms of changing cognitive structures. He showed good convergence between similarity judgment and word association methods. Preece presented sketchy results on the use of the Carroll method, but gave highly encouraging reliability estimates for the association test.

None of the literature cited above report the use of the non-metric measure of goodness-of-fit used in the present study. Further, the use of the semantic differential technique in comparison with the other two methods of uncovering structure appears to be unique in science education research to this study.

2.3 Multidimensional Scaling

The purpose of this section is to outline the differences in assumptions and applications of the three types of scaling procedures used in this study. These are: multidimensional scaling (Kruskal, 1964a, 1964b; Kruskal and Carmone, 1971); points of view analysis (Tucker and Messick, 1963); and individual differences analysis (Carroll and Chang, 1970). Subkoviak (1975) has produced a substantial review of the use of these techniques in educational research.

Initiating the work later extended by Kruskal, Shepard (1962a, 1962b) devised a technique to find the minimum number of dimensions necessary in which to portray a set of n points such that the computed distances between all possible pairs of points are monotonically related to the set of dissimilarities of the original data. The usefulness of this technique depends upon the assumption that monotonic constraints imposed in sufficient number on a set of points will approximate the interpoint distances to within a linear transformation of the dissimilarities.

Shepard has achieved good results with this model. In an artificial example, a set of 15 random points were generated in two dimensions. A set of interpoint distances were calculated, and these served as dissimilarities. The actual coordinates of the points were then ignored in the analysis. Shepard produced a set of points in two dimensions quite close to the original points.

In a second experiment, using data gathered from people, his subjects were asked to rate the degree of similarity of facial expressions in a series of photographs of an actress. The actress had been given specific instructions for each facial expression. The task asked the subjects to give numerical ratings to the difference in facial expression for all pairs of photographs. These ratings, however, were used only as rank orders, not as interval data. The results of the Shepard analysis yielded two dimensions, a horizontal dimension of pleasantness, and a vertical dimension of degree of emotional arousal. The results agree closely with the directions given to the actress and to the results of an earlier analysis, done in a different manner. This original analysis imposed much stricter assumptions on the data than those imposed by Shepard.

In a third example involving similarity ratings of colours the analysis produced a two dimensional circular pattern corresponding very closely to a circular spectrum, with the red and violet ends meeting.

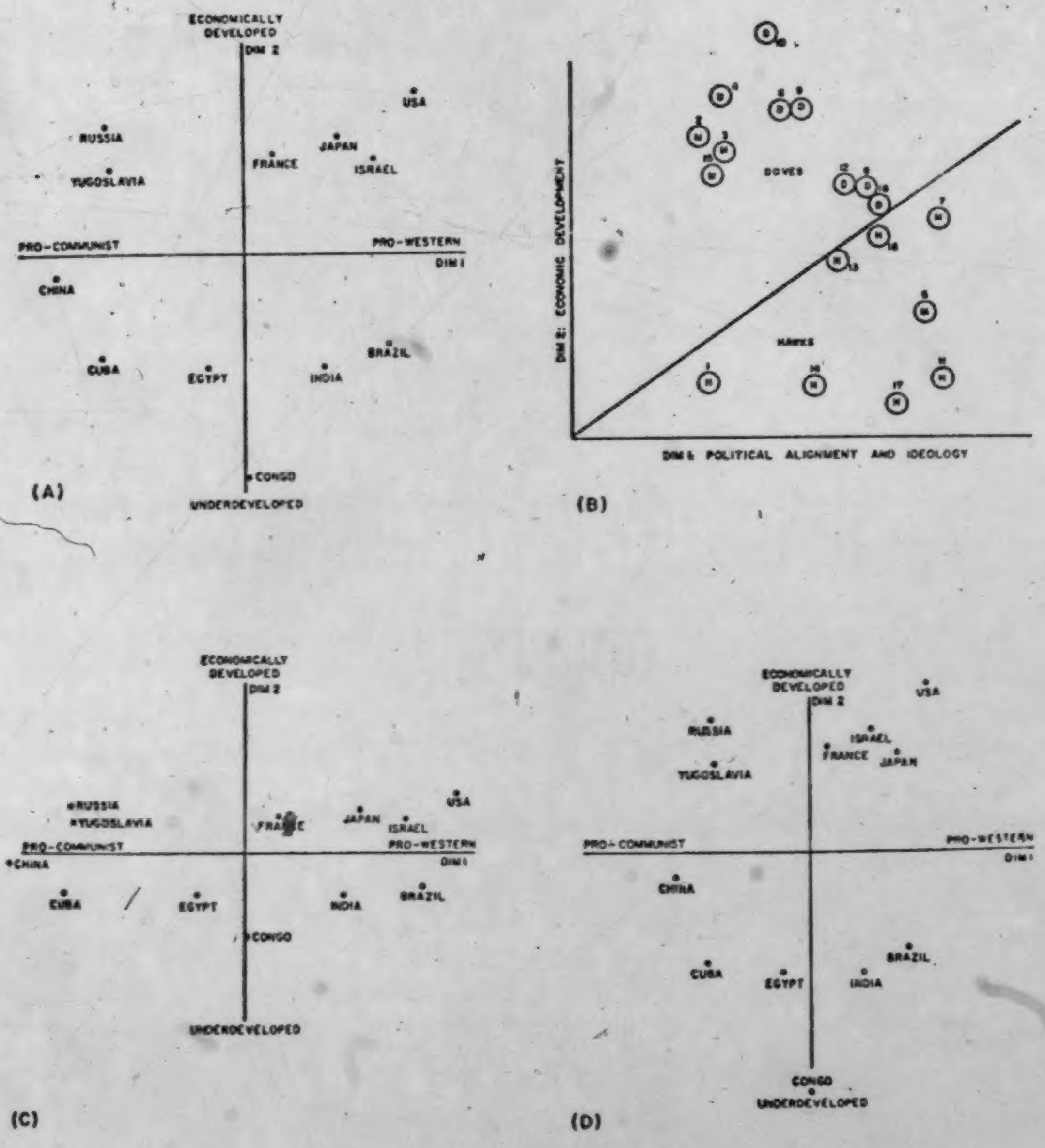
Kruskal (1964a, 1964b), working with Shepard, improved the model by producing a theoretically more rigourous method of computation and by providing a measure of goodness-of-fit of the solution obtained to the original data. His goodness-of-fit measure, stress, is analogous to (square root of) proportion of error variance in a regression analysis. The computational algorithm seeks to minimize stress. The stress can be interpreted roughly as percentage disagreement between solution and data. The stress supplies an objective criterion for deciding when the best solution has been reached. Stress is a value which increases as the relation between dissimilarities and distances becomes poorer. One output of the Kruskal procedure is a plot of stress vs. the number of dimensions for the best possible solution in that number of dimensions. The stress increases as the number of dimensions goes down. If inclusion of an extra dimension significantly decreases the stress, then the dimension should be included. If not, then it should not. Kruskal gave verbal definitions of the quality of the results ranging from 20% ("poor") to 2.5% ("excellent"). The quality of his results was similar to that of Shepard.

Jackson and Messick (1963) have criticized the traditional multidimensional scaling procedures for failure to account for variance among subjects in the manner in which they perceive the stimuli under study. The Kruskal model is able to work only upon the average perceptions of the group of subjects. Jackson and Messick have argued that some subjects may be cognitively complex, and perceive the stimuli as varying in many dimensions, while other subjects may be cognitively simple, and view the same stimuli as varying along relatively few dimensions. They put forward the rationale, and in a companion paper, Tucker and Messick (1963) presented a mathematical method for accounting for the variation in individual responses to a set of stimuli. Tucker and Messick proposed the use of principal components analysis on the matrix of sums of squares and cross products of a subjects by subjects matrix (formed from the subjects by similarities matrix of raw data) to attempt to describe the variance in the perception matrix by a smaller number of dimensions than the original number of subjects. Principal components analysis of the responses of the n subjects is carried out in order to represent the variation in the results in terms of a smaller number of basic subject "types". That is, if they had, for example, 50 subjects, the variance in the scores of the fifty subjects would yield, say, four factors. This result is interpreted by assuming that most of the fifty subjects fall into four types. After the principal components analysis, four "ideal individuals", either composites put together from each of the four groups, or four actual individuals who might be said to personify the types are identified. A Kruskal type scaling is then carried out for each of the ideal types. Each of these scaling results would be based upon a much more homogeneous group of individuals than the scaling procedure applied to all fifty subjects. In such models, different types of idealized individuals yield different geometrical patterns of stimulus-point distances. Ideally, differences in patterns can be traced back to subject characteristics. It may be possible to show that, for example, a two dimensional pattern of distances can account for the responses of those who have been characterized (by some independent measure) as cognitively simple, while, for example, a four dimensional pattern may be necessary for the cognitively complex.

Jackson and Messick reported a Tucker and Messick study conducted earlier in which subjects were asked to rate preceived similarities between international political figures of the 1950's. The principal component analysis revealed the presence of three ideal types. The scaling pattern results for the three types were quite different. One type had a one-dimensional pattern, with a heavy cold-war evaluative emphasis. The second type revealed a two dimensional pattern, interpreted as a Democratic-Republican dimension and an evaluative dimension. The third type had a seven dimensional pattern which defied complete interpretation, but that did reveal political nuances which the other ideal types had not revealed. This third group was regarded as the most cognitively complex. Tucker analysis has also been used by Kass (1971), as described above.

In the present study, the Tucker technique has the potential to identify different types of individuals. In the principal components analysis, those subjects whose views of the concepts are most similar should load strongly on the same dimensions. If those who load strongly on each dimension are taken as a group, it is possible to analyse the perceptions of each of these groups in order to identify differences in perception of the concepts among the groups. Further, it is also possible to analyse the personality variables of the members of each of these groups in order to identify differences among groups on the personality variables. While the Tucker analysis cannot, by itself, separate complex from simple patterns of perception, subsequent Kruskal analysis of the perceptions within each group can.

Carroll and Chang (1970) and Carroll (1972) have developed a scaling method based upon entirely different assumptions from those of Tucker and Messick. Their method assumes that the same dimensions exist in "psychological space" for all subjects, but that the importance or "salience" of these dimensions can vary. The result of their analysis produces a stimulus space plot and a dimension space plot. The stimulus space plot is similar to the results that one would obtain from a Kruskal analysis of group data. The dimension space, however, represents the subjects' positions with respect to the importance which they attach to the dimensions of the group analysis. An example will clarify the nature of the Carroll and Chang analysis. In a classic study, (see Fig. 1) subjects were asked to rate the similarity of a group of twenty countries. Group analysis revealed a dimension which could be interpreted as developed-underdeveloped, and another dimension which could be interpreted as Communist-Western. Subjects were classified independently as doves and hawks. The dimension space plot (upper right) shows that the hawks gave much more salience to the political dimension, while



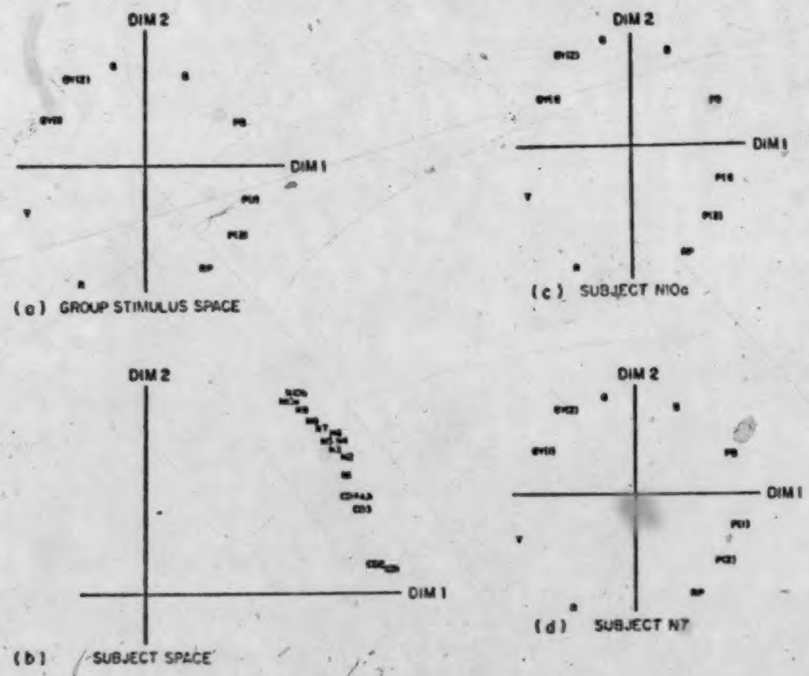
(from Carroll and Wish, 1974)

The Nations Example
Fig. 1

the doves gave more salience to the economic dimension. As a result, the shape of the plot of nations is stretched or shrunken along one dimension or the other. As can be seen in the diagram, Cuba and Brazil were rated as quite similar, because of the salience of the economic dimension, by the doves, (bottom right) but quite different, because of the political dimension , by the hawks (bottom left).

In another example (see Fig. 2) rating similarities of colours, subjects rated as red-green colourblind (bottom) "shrank" the red-green dimension of the stimulus space, while those rated as yellow-blue colourblind (top) shrank the yellow-blue dimension. The Carroll and Chang method is a metric scaling technique. As such, it is open to criticism on the grounds that it imposes too strong conditions on the data. The elegance of the two examples quoted, however, testifies to the robustness of the method with respect to violation of the metric assumptions.

In the present study, the Carroll method offers a technique for identifying individual differences in perception based upon quite different assumptions than the Tucker technique. The Carroll technique postulates the same common n-dimensional space for all subjects, but allows the salience of the dimensions to vary among subjects. Thus, the technique can indicate directly those who share a particular view of the concepts under study. Not only is it possible, as with the Tucker technique, to identify those who share a common view, but with the Carroll technique it is also

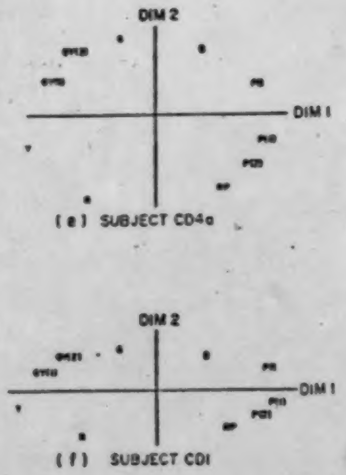


(a) GROUP STIMULUS SPACE

(c) SUBJECT N10a

(b) SUBJECT SPACE

(d) SUBJECT N7



(e) SUBJECT CD4a

(f) SUBJECT CD1

An INDSCAL analysis of Helm's data on color perception produced the group stimulus space* shown in (a) and the subject space shown in (b). The dimensions are normalized so that the sum of squared coordinates on each dimension = 1.00. The coding of the colors in the group stimulus space is as follows: R = red; Y = yellow; GY(1) = green yellow; GY(2) = green yellow with more green than GY(1); G = green; B = blue; PB = purple blue; P(1) = purple; P(2) = purple with more red than P(1); RP = red purple. In the subject space, CD1 through CD4 are four red-green color-deficient subjects (CD4a and CD4b are replications for one subject), while N1 through N10 are normal subjects (N10a and N10b are replications for one subject). Diagrams (c) through (f) are the private perceptual spaces for four subjects.

(from Wish and Carroll, 1974)

The Colourblind Example
Fig. 2

possible to identify the dimensions of concept similarity which are used by the subjects in each group to produce their similarity data. Further analysis by the Kruskal technique, according to Carroll and Chang, is unnecessary. Such analysis, however, was undertaken as part of the present study in order to validate the Carroll analysis findings. As mentioned above (P.38), the dimensions assigned to a subject by the Carroll technique may be conceived as incorporating two best fits, one of the solution to the data, and another of the individual to the group average. A subgroup average solution may be found either directly from the average saliences of the subgroup members on the group average Carroll solution, or by returning to the original data, forming a subgroup average matrix and performing a Kruskal calculation. Since the second method involves only one best fit, and is thus less removed from the data, it was adopted for the present study.

The Carroll technique imposes metric assumptions on the data, while the Tucker technique, if used as Ross (1966) suggests (details given in Chapter 3), is non-metric. Convergent results based upon these two methods which differ in assumptions, calculational techniques, and nature of result are consistent with the Campbell and Fiske (1959) multimethod validity as applied to this study.

2.4 Similarity Rating Tests

The above discussion focused upon the analytic techniques used to analyse the similarity matrices obtained from the concept similarity rating tests presented to the subjects. This section concentrates on the methods by which the concept similarity ratings were gathered from the subjects. These methods are: word association, similarity judgment, and semantic differential techniques.

2.41 Constrained Association Test

The Constrained Association test is based upon a method proposed by Garskof and Houston (1963). Repeated free associations based upon a set of stimulus words which were selected in pairs so that the pairs ranked along a continuum from "high related" to "low related" were given to a group of twenty undergraduates. Subjects were presented with stimulus words, one to a page, and instructed in the continued free association technique. (The free association technique requires the subject to respond with the first word which the stimulus word brings to his mind.) In the Garskof and Houston method, subjects were to write down their responses. The format was as follows:

HOT

hot--------------

hot--------------

hot--------------

.

.

.

The method is called a continued association method because the subject is to continue writing down all words which come to mind by association with the original stimulus word within a given time interval. In the task, subjects had one minute per page. Pages were presented in random order.

Using the responses produced, a relatedness index was calculated for each pair of stimulus words. The index is based upon the assumption that words which produce common responses are related to each other. For each pair of stimulus words, the response list (including the stimulus word) is numbered according to the following algorithm, which will be demonstrated by example. The longer list is found. Responses in the longer list are numbered from the bottom up as shown below. Starting with the highest number in the longer list numbering, the shorter list is numbered downward.

	EGG	(6)		LUNCH	(6)
egg	bacon	(5)	lunch	supper	(5)
egg	breakfast	(4)	lunch	egg	(4)
egg	omelette	(3)	lunch	breakfast	(3)
egg	cheese	(2)	lunch	cheese	(2)
egg	food	(1)	lunch		
egg			lunch		

Matching responses in the two tests are found. The numerator of the RI (relatedness index) is the sum of the cross products of the indices of all matches in the lists (including the stimulus words). The denominator is one less than the sum of all possible cross products if the two lists were identical. In the example, there are matches between egg-word 6 and lunch-word 4, egg-word 4 and lunch-word 3, and egg-word 2 and lunch-word 2. Thus, the numerator of the RI is thus (6 x 4) + (4 x 3) + (2 x 2). The denominator is ((6 x 6) + (5 x 5) +.....(1 x 1)-1). That is, the sum of the squares of the integers from one to the end of the longer list, less one. In the example above, the RI = 0.444.

Proceeding in the above manner, a matrix of relatedness indices is calculated for all possible pairs of stimulus words. Garskof and Houston reported two experiments validating the technique. In the first experiment, 20 undergraduates asociated to each member of 24 pairs of nouns. The pairs of words had been chosen, eight in each group to be "high related" (synonyms), "medium related", and "low related". A thesaurus was used to pair the words. They came from no particular concept domain. Subjects also rated the similarity of each of the 24 pairs of words.

Correlations for individual subjects between relatedness indices and similarity ratings ranged from 0.63 to 0.90. In the second experiment, using the same subjects, Garskof and Houston found one day test-retest results on the association test ranging from 0.72 to 0.90. While it may be argued that the time between tests was too short to discount memory effects as a cause of stability of the measure, such data still speak to the stability of the word association technique.

Converging results between the word association technique and similarity rating techniques offer convergent multimethod validity for the methods of assessing cognitive structure. Word association testing is based upon the view of cognitive structure as a nomological network (cf., Torgerson, 1958) of interrelated concepts whose interrelationships help form the definitions of the concepts. Concept dissimilarity is viewed as the number of concepts which must be "passed through" in traversing the nomological network from one concept to the other. Responses to association tests are "nearest neighbours" to the stimulus in the network. Shavelson and Stanton (1975) expand on this notion from an information processing perspective. If cognitive structure is a valid construct, then a direct rating of similarity of concepts from within that structure should correlate highly with the association technique, which takes as a measure of relatedness the number and proximity of "nearest neighbours" in common, as offered as responses to the stimulus concept.

2.42 Similarity Judgment Test

Similarity judgment tests involve subjects responding to all possible pairs of a set of stimulus words. The items are usually presented in the following format:

EGG
LUNCH

closely related --- unrelated

Subjects are asked to put a mark on the line according to their judgment of the similarity of the stimulus pair. Measures of dissimilarity are taken by measuring from the left hand edge of the line in an arbitrary unit of measure.

In the present study, subjects gave similarity ratings to the 105 possible pairs of the 15 concepts under examination. The format described was followed. The data formed input to the scaling techniques described in section 2.3. As noted in section 2.41, convergent results between association data and similarity judgment data are evidence of the construct validity of cognitive structure as defined.

2.43 Semantic Differential Test

Semantic Differential technique (Osgood *et al*, 1957) is based upon the following three assumptions:

(1) The process of description or judgment can be conceived as the allocation of a concept to an experiential continuum.

(2) Many different experiential continua, or ways in which meaning vary, are essentially equivalent and hence may be represented in a single dimension.

(3) A limited number of such continua can be used to define a semantic space within which the connotative meanings of any concept can be specified.

In the technique, subjects are asked to respond to stimulus words (usually nouns) in terms of seven point bipolar scales demarcated by a pair of antonymous adjectives. The format is demonstrated by the example below.

HYPOTHESIS
sharp *----*----*----*----*----*----*----* dull

Examples of such pairs of adjectives are: good-bad, weak-strong, hot-cold etc. The seven point scale is defined, using the good-bad example, as (1) extremely good, (2) quite good, (3) slightly good, (4) neutral between good and bad, (5) slightly bad, (6) quite bad, and (7) extremely bad.

Osgood et al have amassed a large body of evidence which demonstrates that a substantial proportion of the variance of semantic differential judgments could be accounted for by three dimensions: evaluative (e.g., good-bad), potency (e.g., strong-weak), and activity (e.g., fast-slow). The three will be referred to below as EPA. The generality of the EPA dimensions, as reported by Wiggins and Fishbein (1969), has since been shown to stand up across concept domains, languages, and cultures (Triandis and Osgood, 1958; Tanaka and Osgood, 1965; Jakobovits, 1966)

Wiggins and Fishbein (1969) used the Tucker analysis on a set of semantic differential responses to 15 interpersonal concepts as rated by 97 subjects. Initial analysis of group data revealed the usual EPA three factor pattern, which accounted for 73 per cent of group variance. Individual analysis, based upon ten "idealized individuals", revealed differences in dimensionality, differences in the order of emergence of the factors, and differences in the factors on which the scales loaded for different individuals. For individual responses, the percentage variance accounted for by the EPA factors varied greatly. For example: in one subject, 33 percent E, 31 percent P, and two A factors, 24 and 10 percent; in another subject, 50 percent E, 26 percent P, and no A factor; in another subject, two E factors, 39 and seven percent, 17 percent P, and 32 percent A; and in another subject, 29 percent E, 14 percent P, and 56 percent A.

The large body of semantic differential work in the literature surveyed has not been related to other techniques for uncovering semantic space. Convergence of semantic differential data to that produced by the other two techniques used in the present study would support the convergent validity of the constructs cognitive structure and semantic space. It is reasonable to assume that these two constructs overlap considerably. Such convergence would offer multimethod validity, as semantic differential research comes from a radically different research tradition and body of literature than either word association testing or similarity judgment rating.

2.5 Personality Variables

The underlying assumption of this study is that knowledge of a student's cognitive structure may be a useful tool in planning for and improving his education. The personality variables used in this investigation have been chosen because they have been shown in previous research to have the potential to be of educational significance. (Bart, 1971; Messick, 1970) These measures will be used in attempting a theoretically based explanation of the nature of the subjects as related to their cognitive structure results. Some correlates are obvious and traditional. These are age, grade, I. Q., sex, and science achievement. These will not be discussed further at this point. The personality variables of major theoretical interest are developmental level, analytic-synthetic ability, and cognitive complexity. Developmental level is of theoretical interest for two reasons. First, it has been linked to achievement (Lawson and Renner, 1974, 1975), and achievement in turn has been linked to differences in cognitive structure (Johnson, 1965; Shavelson, 1972). Second, developmental level has been linked to the understanding of analogies (Lunzer, 1962), which in turn is an important aspect of the understanding of the meaning of concepts. Field dependence-independence is of theoretical interest in that it also has been linked to achievement (Hammond, 1976). The notion of acuteness of perception in a visual context carrying over into acuteness of perception of meaning has been investigated at length

(See Hammond, 1975 and Messick, 1970). Cognitive complexity is of theoretical interest in that there is an intuitive expectation that complexity of perception of interpersonal relationships will transfer to cognitive situations.

2.51 Developmental Level Test

Inhelder and Piaget (1958) have defined formal operational ability as the ability to consider all the possible relationships in a situation, rather than merely the actual relationships. That is, a formal thinker can think beyond the perceived actualities of a situation and consider hypothetical possibilities. Further, he has the ability to think in a hypothetico-deductive manner (Lawson, 1976). According to Inhelder and Piaget (1958), formal thought begins to appear in adolescents at about the age of 11 or 12, and is fully functional by about the age of 16. Research done outside the Genevan school has tended to show that Piaget's age estimates are optimistic for more typical populations. Such research has been quite thoroughly reviewed by Hobbs (1975), and need not be reviewed in detail here. However, a few comments must be made about the fundamental inadequacies of this line of research, particularly as it attempts to uncover the factor structure of developmental level.

As a generalization, Lawson and Renner (1975) estimated that 40 to 75 percent of secondary students have failed to reach the level of formal thought. In their research, Lawson and Renner have shown the importance of formal thinking ability in the high school science curriculum. Using a panel of experts, concepts from the biology, chemistry, and physics curricula were divided into concrete and formal concepts. A sample of 51 biology, 50 chemistry, and 33 physics senior high students were categorized by developmental level using four individually administered tasks. Subjects were graded on a scale from one to five on each task, and were then assigned to one of seven groups ranging from early concrete to fully formal. These groups were, in order: early, transitional, late, and post concrete; early, transitional, and late formal. The subjects were administered tests of concrete and formal subject matter concepts. The results were interpreted by Lawson and Renner to show that concrete students could understand only concrete concepts, while formal students could understand both formal and concrete concepts. In a table of percentage correctly answered concrete questions vs. level of development, there is a gradual increase from about 30 percent for transitional concrete to 80 percent for late formal. In a similar table for the formal questions, virtually no subjects below post-concrete had any questions right, but beyond this point, there was a regular increase from 15 percent for post-concrete to 45 percent for late formal. The sample is, however, too small for the formation of any firm generalizations. Because of the connection between achievement and formal thinking ability, it is important to look for a connection between formal thinking ability and cognitive structure. If cognitive structure is to bear any relationship to subject matter achievement, it appears reasonable to expect differences in cognitive structure between concrete and formal thinkers.

It is not completely clear from recent research whether formal ability is unifactor or not. Lawson and Renner (1975) maintained that the conservation of volume task (Karplus and Lavetelli, 1969), the chemicals task and the balance task (Inhelder and Piaget, 1958) are essentially measuring the same ability. Lawson and Renner used stepwise multiple regression analysis to test the improvement on prediction of achievement by one Piagetian task if further tasks are included as predictors. For their six achievement tests (concrete and formal biology, physics, and chemistry) the addition of a second predictor did not significantly improve the squared multiple R. In three of the six cases, the best predictor was the conservation of volume task, and in the other three, the chemicals task. Only one of the six squared R's is reported, at 0.41. Principal components analysis of their data yielded a first factor which accounted for 62.2 percent of the total variance. Thus, they suggested that subjects can be satisfactorily characterized by only one task.

Bart gave the shadows task, the balance task, the pendulum task, and the conservation task (Inhelder and Piaget, 1958) to a sample of 30 above average subjects from each of the age groups 13, 16, and 19 years. Not enough detail is provided to calculate the percent trace, but maximum likelihood factor analysis produced a first factor on which the four tests loaded with coefficients ranging from 0.62 to 0.88. Bart interpreted these data as indicating the unifactor structure of the four tasks. Bart's subjects also wrote three subject matter tests of formal operational ability. When all seven tests and tasks were factor analysed together, all seven loaded on the first factor with loadings between 0.54 and 0.84. The tests loaded on the second factor (28 percent as large as the first factor) with coefficients of 0.24, 0.31, and 0.51. The tasks loaded on the second factor with coefficients from -0.17 to -0.32. Bart interpreted this to indicate that there was a large formal operational factor and a smaller test writing factor in operation. He did not mention the possibility that the first factor was a general intelligence factor.

Lawson and Nordland (1976) administered ten tasks to 96 grade seven subjects. In a principal components analysis, their first two factors, identified by them as concrete and early formal factors, accounted for 55 percent of the total variance. The second factor was called "early" formal because only three percent of their sample had reached the early formal level of development, as judged by their results. All of these studies used individually administered tasks, scored on a scale of four or five points.

The need for efficiency of testing in large scale studies has led to the development of paper and pencil group tests in place of the individually administered tests of formal operations. Raven and Polanski (1974) using Raven's (1973) paper and pencil Tests of Logical Operations (RTLO), a mixture of concrete and formal tasks, required five factors to account (only partially satisfactorily) for the ability measures. These factors accounted for a total of 40 percent of the variance in the total test battery, which included eight other tests as well as the seven subtests of the RTLO. One possible reason for the disparity between the individually administered test results and those of Raven and Polanski may be in the scoring system used. The former usually score subjects on a restricted scoring scale (e.g., 1 to 4 for early and late concrete, and early and late formal). The RTLO is not restricted to such a narrow range of scores. The seven subtests contain from eight to sixteen items each. Although scoring procedures are not provided in sufficient detail in the report, it is possible to picture an implicit rule of thumb operating of the nature: "If a subject is not clearly concrete (2) or not clearly formal (4), give him a '3'." Such a procedure, a function of the scoring system used and not of the nature of the test (i.e., group or individual) could lead to artificially high correlations among tests. This might account for the unifactor structure found in the above research. The RTLO, on the other hand, with more than one item per conceptually distinct ability, may be avoiding the potential problem caused by a restricted scoring system. It is difficult to dismiss the very high loadings which some of the subtests of the RTLO have on some of the factors found in Raven and Polanski's study. Without better empirical evidence, the factor structure of developmental level can be no more than speculation.

The point of the speculation, however, is to comment on the state of the art in the measurement of developmental level. On the basis of the present evidence, the factor structure of formal operations remains an open question. The intuitive appeal of Lawson and Renner's subject characterizations, however, give some measure of support to the use of restricted scoring systems for the purpose of classifying subjects. It seems reasonable to assume that a weighted composite of a representative sample of formal operational tasks can produce sensible subject characterizations, despite the lack of consensus on the factor structure of formal operations. Some of the problem concerning the structure of formal operations may rest with the application of metric factor analytic techniques to the ordinal data produced by the restricted scoring systems.

2.52 Field Dependence-Independence Test

Cognitive style variables have attracted attention of researchers for some years (Messick, 1970). In general, they are an attempt to account for components of ability not accounted for by intelligence. Analytic-synthetic ability is the general name for a large number of variables, including cognitive control (Gardner, 1973; Gardner and Lohrenz, 1969), scanning (Holzmann, 1966), flexibility of closure (Field and Cropley, 1969), levelling-sharpening (Lohrenz and Gardner, 1973), and, most important and longest-lived, field independence-dependence (Witkin, 1950). Hammond (1976) has provided a substantial and detailed review of the area which need not be repeated. The field, according to Klein et al (1967) suffers from an excess of conceptual and empirical overlap coupled with many competing definitions.

In an effort to bring empirical clarity to the area, Messick and French (1975) administered a battery of 34 tests of speed and flexibility of visual, semantic, and verbal closure to 541 naval cadets. Principal axis factor analysis produced a fourteen factor solution, accounting for 46 percent of the variance. The first four factors had eigenvalues greater than one and accounted for 33 percent of the variance. These factors were labelled ideational fluency, flexibility of perceptual closure, flexibility of verbal closure, and flexibility of semantic closure. Intercorrelations among the first four factors ranged from 0.10 to 0.25. Nine of the thirty-four tests loaded significantly on the second factor, which is the one of most interest in the present context. None of the loadings was higher than 0.62. The Hidden Figures Test used in the present study was not part of Messick and French's battery. A factor solution such as that reported by Messick and French is testimony to a lack of adequate isolation of the dimensions of cognitive and perceptual closure by available tests. Despite the difficulties involved in finding relationships, educators have clung to an intuitively held belief that the concept of field independence must be educationally important. This belief is not without empirical support. Satterly (1976) suggested that the reason for this belief lies in assuming a link between the ability to perceive figure apart from ground with the ability to "experience information as discrete from the organized context of which it is a part," and the lack of this ability as a parallel lack of cognitive ability. Vernon (1972) pointed out that interest in this dimension from an educational perspective is justified only if analytic-synthetic ability provides a dimension distinct from intelligence.

Based upon his review, Hammond (1976) concluded that there is enough evidence that the field independence cognitive style variable is distinct from intelligence to warrant further research. Using six classes of grade 12 physics students, Hammond found field independence, as measured by the Hidden Figures Test (French et al , 1965), which is a group version of the Embedded Figures Test (Witkin, 1954) unrelated to verbal and mathematical ability, but related to physics achievement.

Using a sample of 201 boys age 10 and 11, Satterly (1976) found substantial overlap between intelligence and field independence (r=0.41; p<.01), but significant residual correlation between field independence and both mathematics achievement and haptic perception after intelligence was partialled out.

Because of the significant but unimpressive correlations (generally 0.30 to 0.60) among various measures of analytic-synthetic dimension, Wachtel (1972) recommended the use of several measures and a shared variance technique to assess field independence. Due to time and manpower limitations, this suggestion has not been followed in the present study. Field independence-dependence will be assessed, as in the Hammond study, by the Hidden Figures Test. It should be noted that the Hidden Figures Test correlates with the Embedded Figures Test, which may be taken as at least having attained the dignity of age, at r = 0.62 (Davis, 1972). This is one of the largest correlations to be found in this psychometrically and conceptually unsatisfactory area of research.

Based upon the generality of perceptual skills between both the visual and cognitive domains, it is hypothesized that the meanings of concepts perceived by those scoring high and low on the Hidden Figures Test will differ from each other. It may be further hypothesized that these differences in perceptual patterns will be interpretable in terms of the meanings of the concepts rated.

2.53 Cognitive Complexity Te[illegible]

Cognitive complexity is a cognitive style variable which deals with the degree of complexity with which a subject views phenomena, that is, the number of bases or dimensions that a subject uses to make decisions. Of the three main personality variables used in this study cognitive complexity is intuitively the one most likely to be closely associated with cognitive structure. Subjects with a many dimensioned cognitive structure would be considered cognitively complex, while those with a cognitive structure of few dimensons would be considered cognitively simple. Unfortunately, there seems to be little agreement in the literature as to how to measure cognitive complexity.

As Kass has pointed out (1969) in a review of cognitive preference and cognitive complexity, cognitive complexity has arisen from a tradition of personality measurement rather than cognitive measurement. The complexity of judgments in social interaction rather than subject matter content has been studied. However, it seems reasonable to expect a transfer of complexity, viewed as a multifaceted judgmental ability, between the two areas. This expectation of transfer is examined in this study.

Klein *et al* (1967) has pointed out semantic and conceptual overlap of the terms associated with the field. They point out commonality among conceptual systems (Harvey, Hunt, and Schroder, 1961), psychological differentiation (Witkin, 1962), conceptual differentiation (Gardner and

Schoen, 1962), and cognitive complexity (Bieri et al, 1966). In their review, they conclude that there is little correlation among measures of cognitive complexity.

In reaction to this state of affairs, Smith and Leach (1972) have proposed a new measure of cognitive complexity based upon the Repertory Grid System (Kelly, 1955). Kelly's system is also the basis for the measure of Bieri et al (1966). Smith and Leach, however, criticize Bieri's measure as a measure of differentiation rather than complexity. An example of the Bieri technique involves having subjects generate a list of several significant people in their lives, and a list of constructs on which to judge these people. Numerical judgments are placed in a people by constructs matrix. The test is scored by counting the number of times a person is rated the same on a pair of constructs. The total matching score for all pairs of constructs defines Bieri's measure of cognitive complexity. A subject with a high matching score tends to use all his constructs in a similar manner, and so is deemed cognitively simple. Similarly, subjects with low matching scores are deemed cognitively complex. Quoting evidence based upon research with schizophrenics, Smith and Leach suggested that the Bieri measure confuses "complexity" with "confusion." To remedy this, Smith and Leach began with a large (in this example, 13 by 13) matrix of people (to be rated) by concepts (on which to rate them). With subjects supplying both people to be rated and concepts, ratings were solicited on a scale of +2 to -2. A 13 x 13 matrix of correlations between constructs was produced from this data. Thus, a correlation gave a measure of similarity of constructs as used in the rating task. At this point in the analysis, Smith and Leach claimed that they had something analogous to Bieri's measure, that is, a measure of differentiation. They hypothesized that "the fine details of the construct system will be more important for a complex subject than for a simple subject, so that impoverishing the structure will have a more dramatic effect on the relationships between the people for a more complex subject". To impoverish the structure, all significant correlations were collapsed using S. C. Johnson's (1967) hierarchical clustering. In one experiment (N = 27), this measure was found to correlate 0.10 with Bieri's measure of complexity. However, it was found to be significantly related, by the Mann-Whitney U Test (Sigel, 1956) to Harvey's (1967) TIB Test, a projective, paragraph completion test which arose from the early Harvey, Hunt and Schroeder (1961) work. Bieri's measure did not correlate with the Harvey test. However, in a second experiment, (N = 42) the Smith and Leach measure was found not to generalize across content domains, while the Bieri measure did. The correlation between judging people and other topics of interest (e.g., novels) was, by the Bieri measure, 0.35. This finding has significance for the present study in that cognitive complexity, as mentioned above, must generalize from interpersonal judgments to subject matter judgments to be educationally relevant. In a third experiment, (N = 15) Smith and Leach found one-week test-retest reliabilities of 0.76 for their measure and 0.46 for the Bieri measure.

2.6 Summary

This chapter has reviewed the literature concerned with concept relationship research in science education. Also, the scaling techniques used in the present study were reviewed, together with literature on the six tests used in the present study.

In summary, the present study has gathered concept relationship judgments from subjects by three different methods. From these data, cognitive structures, defined as geometric representations of relationships among concepts, were produced by two multidimensional scaling techniques which are based upon different assumptions. Differences among subjects in their perceptions of the concepts studied were related to personality data on the subjects which was gathered by three independent tests. The next chapter presents details of the methods employed in carrying out the study.

CHAPTER 3

PROCEDURE

3.1 Introduction

This chapter outlines the actual procedures used in the carrying out of the study. The development of the instruments used and the pilot work involved are discussed first. The next section outlines the methods used to estimate the reliability of the instruments, along with reliability estimates found in other studies using the same or closely related instruments. The section which follows discusses the design of the study and the sample used. Section 3.5 presents the details of the scoring procedures, and gives justification for their use. Section 3.6 does the same for the analytic procedures.

3.2 Instrument Development

3.21 Constrained Association Test

The set of concepts chosen for this study are syntactical rather than substantive in nature. Because of this, they should be free of some of the subject matter constraints found by Kass (1971) when content oriented concepts were used. Although the concepts themselves are interesting as a subject of study, they serve primarily as a vehicle for the investigation of the methodology proposed in this investigation.

The study was begun by generating a list of concepts associated with the scientific method. Some, such as "evidence" and "conclusion" were expected to be in common use in science classrooms. The initial hypothesis in mind at the time of concept selection was an hypothesis of two dimensions of variation of the concepts, a time dimension, and a certainty dimension.

The feasibility of the study was established by three pilot studies, two informal and one formal. The first involved a group of nine graduate students and faculty members in a science education graduate seminar group. This group performed a modified version of the Kelly test (Smith and Leach, 1972). Each member of the group was given seven triplets of concepts chosen at random from the set of 15 used for the study. For each triplet, the subject was asked to give a way in which one of the three differed from the other two. An analysis by the investigator of the dimensions of difference indicated by the subjects found the two main clusters as hypothesized. A third, considerably smaller cluster, might have been labelled as theoretical vs. practical. These three clusters accounted for about 90 percent of the responses to the test.

A second pilot study involved a group of 19 physical science student teachers. All members of the group had at least one degree in the physical sciences. Subjects were asked to respond by word association to the 15 concepts used in the study. Concepts were presented in a different random order to each subject. Responses were in written form. Concepts appeared one to a page, with a column of blank spaces for responses under each. Subjects responded to each concept for one minute. The subjects were constrained to respond with "scientific words". This constraint was later modified to "think of the scientific meaning of the word and respond with the first word which comes to mind". This study focused on fluency of response, and also produced pilot data for use in testing and debugging computer programs used in the analysis. As a result of this pilot study, it was established by chi-square test that there was no significant difference in number of responses related to either stimulus concept or order of presentation. There were, as would be expected, significant differences among subjects. Kruskal analysis of the group average relatedness indices produced by this group revealed an easily interpreted spatial representation in either two or three dimensions. It was found, however, that the hypothesized dimensions of time and certainty were confounded. In retrospect, this seems entirely reasonable. As a scientific enterprise proceeds in time from, for example, "puzzle" to "law" or "conclusion", the degree of certainty also progresses.

The third pilot testing involved three grade 9 science and three grade 12 biology classes. Each class in each grade completed two of the six tests which were administered to the study sample. This testing was useful in establishing timing, clarifying directions, practising protocols, and providing, in conjunction with a return visit to the grade 9 classes one month later, some test-retest data. These data will be described below.

The final version of the constrained association test was presented using the modified constraint just described. That is, subjects were asked to "think of the scientific meaning" of the concept rather than to "respond with scientific words". There were fifteen different random orders of pages, each beginning with a different concept. The repeated pages were the first page and second last page of the booklet. The first page was used in the primary analysis. Appendix A presents the directions and a sample page of the text. With one minute per concept, and one concept repeated as a check on consistency, the test took 16 minutes. With time for distribution, practice, and collection, administration time was about 25 minutes. The final test form was photo-reduced by half from the original typewritten copy on 16 pages of 8 1/2 by 5 1/2 inch paper. There was no evidence of inability to read the reduced type on the part of the subjects.

3.22 Similarity Judgment Test

There are 105 possible pairs of the 15 concepts of interest. In pilot work with the student teacher group, concept pairs were presented seven to the page, with two pages for practice, for a total of 17 pages. The practice pages came first and were the same as the second and fourth last pages. All subjects had the same random order. Scaling of group average results showed a good comparison with the word association data results. In the final study, a repeat for consistency was incorporated. Concepts were presented in reduced type on half pages, using both sides of the page. There were ten pairs per side, seven pages, for a total of 140 judgments. Two random orders were used, one the exact reverse of the other. The first ten pairs were for practice, and were not scored. The last five were repeats introduced to fill an exact number of pages, and were ignored. One of the seven pages was a repeat, placed either immediately after the practice page or last in order to maximize its separation from its duplicate. The practice examples were repeats from near the end of the test, and the fillers were repeats from near the beginning of the test. Because some subjects repeated the page with the practice examples, and some the page with the fillers, there were subjects who repeated either 10, 15, or 20 pairs. In the pilot work, a measuring device scoring the ratings on a scale of 25 points was used. Since it seemed to offer no improvement over a scale of nine points, the scale with larger units was used. Such a scale division size is in keeping with Miller's (1956) recommendation. Appendix A presents the directions and a sample page of the test.

3.23 Semantic Differential Test

The pilot version of the semantic differential instrument presented 20 scales on which the subjects rated 15 concepts. These were chosen as follows: four from each of the standard dimensions from a list of adjectival pairs and the dimensions on which they load (Osgood and Suci, 1955), and eight from the descriptions produced by the graduate student and faculty pilot study group referred to above. The intention was to cover any dimensions expected from the EPA factors, and also to cover any dimensions unique to the concepts chosen. Pilot work showed that subjects would not be able to finish such a lengthy test in the time available, so the test was shortened to only twelve adjectival pairs. These were chosen to give three for each of the EPA dimensions, and three unique to the study. According to Osgood and Suci's (1955) results, the nine scales chosen all load highly on one factor only, three on each of the EPA factors. According to Maguire's recommendations (1973), all subjects were presented with the adjectival pairs in the same random order. The concepts were also presented in the same random order for all subjects. Since both sides of the page were used, it was necessary to introduce a sixteenth concept, "generalization", which was ignored in analysis. Subjects responded to both sides of nine half pages, allowing one repeat for a consistency check. The repeat was placed first or last in order to maximize its distance from its duplicate. That is, it was first if one of the last pages was repeated, and last if one of the first pages was repeated. Examples of the instructions and a sample page can be found in Appendix A.

3.24 Developmental Level Test

Despite the "blunt instrument" nature of written Piagetian tasks using restricted scoring systems, they are a necessity in this investigation due to time constraints and sample size. Since no conclusions are to be drawn regarding the factorial structure of formal thought, this does not impose any great limitation upon the results.

Despite Lawson and Renner's (1975) recommendation to use only one task to characterize subjects, it was decided to use a composite score based upon four tasks. If formal thought is, in fact, multifactor, then a composite score is probably more appropriate. This appears reasonable because, in this study, one formal ability can not be said to be inherently more important, or relevant, than another.

The first test item (see Appendix A) is the conservation of volume task used by Karplus (Karplus and Lavetelli, 1969). Departures from the administration method of Karplus were necessary in order to allow administration of the developmental test and one of the concept relationship tests within 50 minutes, the time available for testing in one junior high period. A modification was added because of the group situation and time constraints. According to Karplus, after subjects make and explain their predictions, they are shown the results of the demonstration and are allowed, if they were wrong, to correct themselves by explaining the discrepancy. Despite being told the test did not count, the tendency to change responses seemed to occur in a significant number of subjects in pilot work. Thus, subjects in the main study were not shown the results of the demonstration until their response sheets had been collected. There was no opportunity for a second explanation. This departure from Karplus' method may cast doubt on data based upon this one item only, but seemed necessary in view of the circumstances.

The second item is a combinatorial task taken directly from Hobbs (1975). It is a logical equivalent of the Inhelder and Piaget (1958) chemicals task. Item 3, a controlling variables task, is also from Hobbs, although he used it for subject training rather than testing. Item 4, another variety of controlling variables task, uses a diagram from Hobbs, but the questions asked are different. A version of Karplus' "Mr. Tall and Mr. Short" task (Karplus and Lavetelli, 1969) was included in pilot work, but dropped because of the time required for its administrastion. A composite score, based upon the four items in the final version of the test was used in the main study. Details of scoring are presented below. The four items were selected to represent two of the principal types of reasoning found indicative of formal reasoning (Inhelder and Piaget, 1958), that is, a conservation of volume task and a combining variables task. These tasks are also the tasks found to be the best single predictors of achievement by Lawson and Renner (1975).

The conservation of volume task was administered first, with all subjects watching the demonstration together. After the first part of the demonstration, subjects worked through the test booklet at their own pace. Tasks were presented one to a page. There was no time limit, but all subjects finished within twenty-five minutes. After the booklets had been collected, the demonstration was completed. The text of the test appears in Appendix A.

3.25 Field Dependence-Independence Test

As was mentioned above, it was decided to use the Hidden Figures Test (French et al, 1965) as a measure of this variable. The Hidden Figures Test, commercially available from Educational Testing Service, is a timed test of the ability to find simple geometric patterns embedded in more complex patterns. The test is in two ten minute halves, with sixteen items per half. The format is five-alternative multiple choice. The choices, which remain the same throughout the test, are printed and labelled A to E at the top of each page. Each half of the test occupies two pages, which can be viewed at the same time. A correction for guessing is applied. With time for distribution, practice, and collection, administration time is about 25 to 30 minutes. Because of the commercial availability of the test, is does not appear in the Appendix.

3.26 Cognitive Complexity Test

Seaman and Koenig (1974) produced a system by which they compared several measures (that is, scoring systems) of cognitive complexity using the same response data. The cognitive complexity measure used in this investigation is based directly upon one of their scoring systems, and very similar to that of Bieri. Subjects are presented with general descriptions of six significant individuals. Examples of such individuals are "person of same sex you feel uncomfortable with", "your favourite teacher from this year or last", etc. The test presents a series of six criteria (outgoing-shy, decisive-indecisive, friendly-unfriendly, cheerful-illhumoured, dominant-submissive, and considerate-inconsiderate) with which the subject is to rate the six individuals on a scale of one to five. A score of cognitive simplicity (the inverse of complexity) is found by counting the ties in the scores of each individual on all possible pairs of continua. This amounts to a measure of the "halo effect" in the subject's rating of the individual. The test was administered on one page of paper, with directions on one side and the matrix on the other. Subjects were given an example and allowed to practise the task. The privacy of the people they were rating was carefully preserved by the directions. Explanation time for this test was about ten minutes, with time for completing it varying from ten to twenty minutes. In every junior high class, the investigator was asked the meaning of the terms "dominant" and "decisive". These were defined, for the whole class, as "bossy" and "able to make decisions", respectively. The text of the test is presented in Appendix A.

3.27 Generated Variables

Sections 3.24 to 3.26 describe the personality variables of major theoretical interest in the investigation. The following section discusses other variables which were generated from the data during the course of the study. They can be divided into two categories, those dealing with fluency on the word association test, and those dealing with personal consistency on the three relationship tests. A good deal of variation was observed in the ability of subjects to cope with the constrained association task. Because of this, the following variables were generated as being potentially useful in the analysis: total number of responses produced, total number of responses consisting of original keywords, percentage of responses using the original keywords, average relatedness index generated by the subject, personal consistency scores (to be described in section 3.3) for each subject on each of the three concept relatedness measures, and overall personal reliability (section 3.3). The first, second, and fourth of these have been investigated, as described in section 2.2, by Johnson (1964, 1965, 1967) and Shavelson (1972, 1973, 1974).

3.3 Instrument Reliability

3.31 Constrained Association Test

As mentioned above, Preece (1976a) reported a test-retest reliability over one month of 0.86 for a sample of eighteen year old physics students (number in sample not reported). Since the stability of a group average depends upon the sample size, such a figure is difficult to interpret. There is little available in the literature regarding the reliability of individual measures of word association tests.

The reliability of the data has been estimated in several ways, all involving test-retest stability. Test-retest data over one month are available on a sample of nineteen grade nine subjects used in the pilot work. This reliability may be reported in several ways: first, and yielding the lowest "reliability" would be an average over all subjects of the correlations between relatedness indices produced by each subject on the two occasions; second, a similar calculation for group average data; third, correlations between the loadings of the concepts as a result of Kruskal analysis of the group average data for each occasion; and fourth, a goodness of fit measure using the nonmetric fit test described above for group average data over the two occasions.

In the main study each subject responded twice to one of the concepts. A relatedness index calculated between the two sets of responses (adjusted to compensate for the fact that the first words in the two lists are always identical) gives a measure of the subject's personal consistency on the one testing occasion. Such a measure is crude at best, and certainly is itself subject to indeterminate measuring error. In retrospect, it would have been worthwhile lengthening the test by two minutes and getting duplicate responses for three rather than one word. However, the calculation which was done may have some meaning as a measure of consistency.

3.32 Similarity Judgment Test

The literature surveyed does not report data on the reliability of similarity judgments. Johnson (1967) reported correlations between word association data and similarity judgment data in the order of 0.70. A possible way of estimating reliability would be to calculate the goodness of fit between individual matrices and the group average. Such a procedure is rejected because, in addition to equating conformity with reliability, it would be costly in terms of computer time. The method, limited though it is, chosen for this study is to report the Pearson product-moment correlation between the ratings for each individual over the 10, 15, or 20 pairs which he rated twice. Correlations were adjusted by the Spearman-Brown formula to give a consistency measure based upon 20 repetitions. While it would be possible to calculate the stepped-up correlation as if the repetition were over all 105 pairs of concepts, this was not considered warranted.

3.33 Semantic Differential Test

DiVesta and Dick (1966) and Norman (1959) have investigated the stability of semantic differential scales. DiVesta and Dick measured four-week test-retest stability using a total score from the two scales which loaded highest on each of five factors. The sample of 500 children, grades 2 to 7, rated 100 concepts on 27 scales. Stability estimates averaged over the five factors ranged from 0.30 for grade 2 to 0.55 for grade 7. Stabilities for the EPA factors in grade 7 were: E, 0.78; P, 0.55; A, 0.54.

Norman (1959) proposed the use of a stability estimate which measures the actual size of shifts in the rating of each concept on each scale divided by the maximum shift possible. Using 30 adults rating 20 concepts on 20 scales his measure produced less than 30% shift in all cases. Pearson product moment correlations on the same data gave correlations of the order of 0.66. Since the Pearson r is more easily interpreted, there seems to be no advantage to using Norman's other stability measure. When Norman moved from stability of scales to stability of factors, stability of the EPA factors (using 8,3, and 3 scales) were in the range of 0.75 to 0.79. When Norman computed correlations on individual rather than group test-retest data, the highest correlation he found, out of 500 subjects, was 0.37.

Heise (1969) investigated the assumptions behind analysis of semantic differential data. One assumption involves the bipolarity of the scales. Most scales commonly used are a pair of polar opposites. Assumptions made when employing the semantic differential are that: (1) each member of the polar opposite pair is the same distance from the origin; and (2), members of different polar opposite pairs are at equal distances from the origin. According to Heise, the assumption of bipolarity of scales is not perfectly valid, but is close enough for most purposes. A second assumption involves the metric defined by the terms "slightly", "quite", and "extremely". Heise quoted an earlier study by Messick (1957) in which the method of successive intervals revealed correlations of from 0.98 to 0.99 between actual and assumed metrics over nine common bipolar scales. This research was cited in support of the use of metric methods on semantic differential data. Based upon the work of Wiggins and Fishbein, Norman, and Heise, it seems reasonable to expect an acceptable level of stability and internal consistency on semantic differential instruments when used with the age groups in this study. However, interpretation of factors and generalization of results should be undertaken only with caution.

As mentioned above, subjects repeated two pages of the semantic differential test. Correlations between their responses on these occasions were reported, in a manner similar to the similarity judgment consistency measures, as semantic differential consistency measures.

3.34 Consistency on Similarity Ratings

Subjects' data were organized to produce a similarity matrix for each of the three concept relationship tasks. It is possible to calculate an overall subject consistency estimate by assuming that these matrices are, in fact, products of the same cognitive structure and should ideally be identical. Three correlation coefficients were produced for each subject by taking the three tests in pairs and correlating the vectors of the 105 similarities produced. These three correlation coefficients were converted to Fisher's Z (Ferguson, 1971), averaged, and converted back to correlation coefficients. This variable is reported as one of the generated variables of interest. It may be interpreted as reflecting both the attention paid to the tasks by the subject and the nature of the cognitive processes being tapped. Correlations for all subjects were low enough that the use of Fisher's Z to avoid ceiling effects in averaging was unnecessary.

3.35 Developmental Level Test

There is considerable conceptual difficulty with the problem of reliability of developmental level measures. Test-retest methods, because of the small number of tasks involved, are subject to strong memory effects. If a longer time interval is used, there is the real possibility of cognitive growth confounding the results. Measures of internal consistency, such as KR-20 and principal components analysis, assume the unifactor structure of formal operations which is not a closed question. Nevertheless, both these calculations are reported as estimates of reliability.

3.36 Field Dependence-Independence Test

Hammond (1976) reported correlations between the Hidden Figures Test and the more established Embedded Figures Test (Witkin, 1950) in the order of 0.76 from Witkin, and 0.45 from other workers. Jackson _et al_ (1964), in attempting to develop group versions of the Embedded Figures Test, produced three versions of tests similar in intent and content to the Hidden Figures Test. They reported correlations of about 0.60 between their tests and the Embedded Figures Test. While recognizing the inapplicability of KR-21 calculations to speeded tests, they reported KR-21's of the order of 0.75 for their various tests. Fleishman and Dusek (1971), using a sample of 85 enlisted army males, reported a test-retest coefficient over a few hours of 0.72. Boersma (1968), using a sample of 105 undergraduates, reported a test-retest coefficient over ten weeks of 0.63. He also reported KR-20's on these two administrations of the test at 0.79 and 0.87. Reliability of the test for this study will be estimated by split-half correlations between the odd and even items over both halves of the test.

3.37 Cognitive Complexity Test

Seaman and Koenig (1974) presented a summary of the problems involved in achieving consistency of measurement of cognitive complexity. For example, in the Bieri or similar systems, if dichotomous rather than Likert type scales for rating by the subjects are used, the analysis produces more ties and greatly affects the results. Tests of cognitive complexity ask for ratings on both positive people (those to whom the subject feels attracted), and negative people. Seaman and Koenig compared several methods of measuring cognitive complexity. They compared scores using Bieri's tied rating methods for all people rated, for positive people only, and for negative people only, along with scores proposed by Fiedler (1967) , involving the highest rating for a negative person and/or the lowest rating for a positive person, and an information density model proposed by Scott (1962). The Fiedler measures fared quite poorly in the comparison. Factor analysis showed that the Scott and Bieri methods loaded quite well on the same factor. A variation of the Bieri method, as used by Seaman and Koenig, has been chosen over the Scott method for this investigation. Scoring details will be provided in section 3.6.

Estimates of the reliability of the cognitive complexity measure used in this study have been obtained from test-retest data over one month from one of the grade 9 pilot classes.

3.4 Sample and Design

Each of the concept relationship tests was paired with one of the personality variable tests for administration on the same testing occasion. Pairing was done on the basis of time needed for administration. The pairings were: the Hidden Figures test with the similarity judgment test; the developmental level test with the constrained association test; and the cognitive complexity test with the semantic differential test. The personality test was always administered before the concept relationship test.

The target population of the study is the population of high school science students. It is the intention of the investigator to generalize to individuals only. Since no generalizations to classes, grades, or schools are proposed, the restriction of the sample to two grades and four schools is not viewed as a limitation of the study. Restriction of the sample to one urban-suburban school system, however, should be viewed as a limitation on the generalizability of the results.

With three testing sessions needed per group, it was planned to test six classes at each grade level, grade 9 and grade 12, each class receiving the testing sessions in one of the six possible orders. Such a large sample was deemed necessary because substantial sample attrition was expected due to the number of sessions needed to obtain complete data. Subjects were kept in the sample only if they completed all six tests, and if their I.Q. scores (for grade nine) and last year's achievement score were available. The particular grades used were chosen because the school board administered system wide I.Q. tests in grade nine, and because a maximum possible spread between the two halves of the sample was needed to best investigate developmental aspects of the study. Biology students were chosen because they are usually more typical of the high school population than either chemistry or physics students. Also, biology students were easier to obtain due to larger enrolments in biology.

As anticipated, there was some difficulty obtaining a sample for the study. Most junior high schools in the area operate on 40 or 45 minute periods. Only a few had the 60 minute periods necessary. Further, the study was done in April, and many grade twelve teachers were reluctant to relinquish three hours of class time so close to the end of the term. Six grade nine classes were obtained, four in one school and two in another. Only five grade twelve classes were obtained, three in one school and two in another. The sample size desired was not substantially affected, as the two classes obtained from one school were team taught, having double the normal enrolment. For the senior sample, one of the six possible orders of testing was randomly discarded.

Testing had been planned so that each class would be visited at the same time each week, for three weeks, with all administration done by the investigator. Due to the difficulties of Easter, field trips, etc., this was not possible. Gaps between testing sessions ranged from four to nine days, with one of fourteen days. Thirty of the thirty-three sessions were administered by the investigator, and the remaining three by the investigator's thesis supervisor. A common script was followed, and all questions and irregularities recorded. The second investigator observed the principal investigator in two testing sessions to insure uniformity of administration. Sample attrition is summarized in Table I. Most of the subject errors involved misunderstanding the cognitive complexity test or producing pages of the semantic differential test with no variance. The "other" errors were spread evenly over the remaining four tests. Included in the "error" category are those subjects who quite obviously were not treating the tests seriously. The voluntary nature of the task combined with beautiful spring weather to account for the high absenteeism in the grade 12 sample. While it may be argued that the sample suffers from differential absenteeism, this is not viewed as a serious hindrance to the generalizations which it is possible to make from the study. Undoubtedly, the average ability of those making errors on the test is lower than that of those not making errors. However, since the personality variables of the sample are reported, and since it is not an intention of the study to generalize to "typical classes", there should be no major problem due to attrition.

TABLE I
SUMMARY OF SAMPLE ATTRITION

	Class												
	1	2	3	4	5	6	7	8	9	10	11	Tot	Tot
Grade	9	9	9	9	9	9	12	12	12	12	12	9	12
Total Size	31	26	25	26	26	26	34	21	19	34	26	160	134
Absenteeism	4	4	6	4	5	5	16	7	7	17	13	27	60
Incomplete Records	6	2	3	3	5	2	0	1	0	1	1	21	3
Errors Cog. Comp.	3	3	0	1	0	1	1	0	2	0	0	8	3
ERRORS COLLATION	0	0	1	0	1	0	0	0	0	0	0	2	0
No Variance Sem. Diff.	0	1	2	2	0	3	2	0	1	1	1	8	5
Errors Other	1	3	1	2	5	3	2	1	3	3	0	15	9
Sample Size	17	13	12	14	10	12	13	12	6	12	11	78	54

3.5 Scoring Procedures

3.51 Constrained Association Test

Responses to the constrained association test were hand scanned, and the data cleaned up for machine scoring. In this process, spelling was corrected, extraneous words in the responses, such as "the" and "of" were eliminated, responses of more than one word were linked together to form a long pseudo-word, and the grammatical form of some responses was changed (e.g., verbs were put in present tense). It was expected from pilot work that there would be many cases of responses which were different words, but which came from the same root, such as "conclude" and "conclusion". In order to have these words contribute to the relatedness indices, only the first six letters were compared by the scoring program. This eliminated most cases, except for "prove" and "proof". In such cases, "prove" was changed to "proof". It is argued that such minor changes in the responses is in keeping with the spirit of the relatedness index.

The technique used in this study to calculate the relatedness indices differs from the Garskof and Houston technique in three ways. First, the response is constrained by asking the subject to concentrate on the scientific meaning of the keyword. The nature of "scientific meaning" is, of course, left for the subject to implicitly define for himself. Second, Garskof and Houston took the RI's as the results of their experiment. In this study, the RI matrix is treated only as the input to the scaling techniques described above. The indices have the status of similarity measures, to use the scaling terminology.

The correction factor of minus one proposed by Garskof and Houston is not used in this study. Garskof and Houston reasoned that, since the first words on the two lists could never be the same, the index could not equal 1.00 as a theoretical maximum. The correction factor allows the RI to be 1.00 in a case where two words elicit each other first as responses, and the rest of the words on the two lists are identical in nature and position. The correction factor has not been used in this study because it allows no distinction between short lists and long lists which are maximally related. Using the correction factor, if two words elicit each other, and then are followed in the response list by either one or ten more identical reponses, the RI will be 1.00. By not using the correction factor, the longer identical lists will produce a higher RI. The disadvantage of this procedure is that the theoretical maximum of the relatedness index is now less than one. Analysis shows that, for the usual range of values found, the difference in calculation makes no practical difference. For example, in the example relatedness index calculation of section 2.41, the value is 0.444 using the correction, and 0.439 without it.

3.52 Similarity Judgment Test

For the similarity judgment tests, scoring was done by laying a clear plastic sheet with vertical divisions on it over the response pages. If a subject missed one judgment, the value of "5" was arbitrarily supplied in order not to lose the subject from the sample because of a small omission. If he missed two judgments, he was dropped from the sample. Only three of the 132 subjects have had a response supplied in this manner. It is doubtful that such tampering would change even individual results by any noticeable amount.

3.53 Semantic Differential Test

In the semantic differential test, there seemed considerable evidence of subjects refusing to take the requested judgments seriously. This would account for the dozen subjects who simply ran down the pages marking the same point on every scale. These subjects were easily detected when an attempt was made to form a correlation matrix of their scores. Such subjects, as indicated in Table I, were dropped from the sample.

3.54 Developmental Level Test

The developmental level test was scored as follows. Each item was worth two points. Item one was the volume displacement task, and was worth either 0 or 2 points. Under the testing conditions for item 1, there was no opportunity to award part scores. All other items were scored 0, 1, or 2.

In item two, the hamburger question, if a subject produced an incomplete and unsystematic response, he scored zero. If he produced a partly systematic but incomplete response, or if he filled the page producing permutations on the order of a few of the correct responses, or if he happened upon a complete solution in what appeared to be a random manner, he scored one. If he proceeded in a systematic manner, and showed evidence that he was aware of forming combinations of more than two ingredients at a time, he scored two even though he may have missed one or two of the fifteen combinations. As a point of interest, only one or two subjects mentioned the possibility of the sixteenth hamburger, the plain one.

Item three was the screws puzzle. If a subject got none or one of the three parts, he scored zero. For two correct, he scored one, and for all three, he scored two. This procedure assumes that getting only one of the three parts is luck rather than skill.

Item four was the belts question. There were eight parts to this item, with scores ranging from zero to eight. In the absence of any evidence on the behaviour of this item with respect to developmental level, a completely _ad hoc_ scoring procedure was devised. Since the majority of subjects found the item very easy, a method was desired to give a satisfactory distribution between scores of zero, one, and two. On the eight point scale, five or less received zero, six received one, and seven or eight received two.

On the total developmental test, a subject could score from zero to eight. This scale was divided into equal thirds. Scores of zero, one, or two were grouped as concrete, six, seven, or eight as formal, and three, four, or five as borderline. This system allowed a subject to miss one task completely or be borderline on two tasks and still be graded as formal operational. At the other end of the scale a subject could be borderline on two tasks, or get only one completely correct and still be classified concrete. The system tended to err on the side of putting subjects in the middle group. This scheme produced a reasonable spread of developmental level, which was roughly in keeping with the distributions reported by other workers (c.f., Lawson and Renner, 1974; 1975). There was not, however, as much difference between the two grades as might be expected.

3.55 Field Dependence-Independence Test

The Hidden Figures test was scored by the scoring scheme supplied (French *et al.* 1965), both with and without a correction for guessing.

3.56 Cognitive Complexity Test

The cognitive complexity test produced a six by six matrix of ratings of acquaintances on characteristics. The scoring procedure looks for ties in the ratings of the same person on different characteristics. With six characteristics, the maximum number of ties is fifteen per person, for a total of 90. Scores of complexity were the number of ties subtracted from 90.

3.57 Expurgation of Data

In studies of this type, caution must be taken to identify those subjects who refuse to take the tests seriously and produce meaningless or frivolous results. Hand checking of the constrained association data uncovered two subjects who were obviously playing jokes. Random or systematic pattern production, without regard for the task in the semantic differential test resulted in the dropping of 13 subjects from the sample. Any such subject remaining would, on the individual scaling analyses, produce patterns so isolated and unique that their patterns would not be taken as honestly reported cognitive structures. Such patterns would almost certainly be interpreted as error in the data. There is no evidence that those subjects who remained in the sample did not treat the tests seriously.

It is also important to watch the individual administrations of the tests for variation. Certain questions were expected from pilot studies, and answers were scripted. Occasionally other questions arose and were dealt with. None of the administrations was substantially different from the others.

3.6 Analytic Procedures

The following considerations apply to the formation of the similarity matrices. Responses to the constrained association task were used to produce a set of relatedness indices which were used directly as similarities. As calculated by Garskof and Houston, RI's have a range of 0.00 to 1.00. The method of calculation used in this study and the maximum value are slightly different, as has been discussed in section 3.61. Responses to the similarity rating task produced a set of dissimilarities ranging from 1 (most similar) to 9 (least similar). These values were subtracted from 10 tc produce a set of similarities. The semantic differential results were used to produce a set of correlations among the patterns produced for each of the concepts rated. The theoretical range of the semantic differential correlations was -1.00 to 1.00.

The similarity judgment data are affected by (a) response sets, giving varying mean similarities produced by different subjects, and (b), the tendency to exaggerate or attenuate similarities, producing varying variances across subjects. Since these possibilities had the potential to confound the analysis, and since they were not considered to be of theoretical interest, the similarity judgment data were standardized to a mean of 10 and a standard deviation of 2.00 within each subject. The confounding thus avoided would have allowed those subjects with the largest variances in similarity to dominate any group average of which they were a part.

The semantic differential data are also open to the possibility of correlations among concept response patterns being enlarged due to response sets. For example, a subject might tend to view most concepts presented as "good" or "weak". His inability to make distinctions within each of these dimensions would increase his average correlation, and allow him to dominate a group average. To avoid this problem, the semantic differential correlation matrices were also renormed to mean 10.0 and standard deviation 2.00.

In the constrained association test, the tendency for a subject to use a relatively small pool of words from which to draw his responses, especially to use some of the concepts as responses to other of the concepts, would produce a large average relatedness index compared to that of a subject who responded from a larger pool of words. This tendency was judged to be of sufficient theoretical interest that the relatedness index matrices were analysed both as calculated and as renormed to mean 10.0 and standard deviation 2.00. Thus, each subject produced a total of four matrices for further analysis: relatedness indices scaled and unscaled, similarity judgment, and semantic differential. For brevity, the last two mentioned tests will not be referred to as scaled, since they are never discussed in the unscaled form. The matrices will be referred to below by these terms.

Considerable research has been carried out (Klahr, 1969; Wagenaar and Padmos, 1971; Isaac and Poor, 1974; Clark, 1976) on the significance of the stress function for interpretation of results. Klahr (1969) did a Monte Carlo study of the Kruskal scaling technique. His results showed that the method had the ability to determine structure for points when, in fact, no such structure existed. Since scaling procedures always produce numbers, the experimenter must decide subjectively the difference between interpretable and uninterpretable results. Klahr's results emphasized the danger of overinterpreting results particularly where a small number of data points are used. To combat this overinterpretation, he suggested that the range of acceptable stress values should be considerably smaller than Kruskal had originally proposed. Klahr also noted that the resulting geometrical mapping was unreliable for fewer than ten points.

Kruskal also proposed a second "S" function, which he called Stress 2 (see Kruskal and Carmone, 1970). Kruskal and Carmone have produced revised estimates of what constitutes "good" or "poor" stress for different numbers of data points and for both Stress 1 and Stress 2. According to Kruskal and Carmone, stress 2 values are generally about twice the size of Stress 1 values. The Monte Carlo studies (Wagenaar and Padmos, 1971; Isaac and Poor, 1974) reported which investigate the effects of error on stress all present their results in terms of stress 1. Since these studies are relevant to a discussion of the error in the present data, all stress values are reported as stress 1. Using the Schonemann and Carroll (1974) non-metric fit procedure as a measure of congruence, scaling the same data using stress 1 or 2 produces solutions which correlate at least 0.95.

Considerable work has been done on the interpretation of multidimensional scaling results. Wagenaar and Padmos (1971), Isaac and Poor (1974), and Spence and Graef (1974) have all carried out Monte Carlo studies on the effects of error on the interpretability of scaling results. The studies all involve generating results for several different numbers of points in several different numbers of dimensions when the true dimensionality of the solution is known. The similarities are then perturbed by several known amounts of error, corresponding to subject error in estimating the similarities. The effect of these various conditions on the stress values of the final solutions can then be observed. Spence and Graef have produced results for configurations of 12, 18, 26, and 36 points, but only present detailed results for the 36 point case. Wagenaar and Padmos dealt with 8, 10, and 12 point configurations. Isaac and Poor dealt with, among others, configurations of 12 and 16 points. On the basis of Isaac and Poor's study, the data of the present study are best interpreted as having a real dimensionality of three dimensions, and as containing about 40 percent error. The stress 2 values of about 50 percent are not unreasonable, and are well below the values reported for 16 random points. An attempt at extrapolation from the Wagenaar and Padmos data would indicate even less noise in the data of this study than that suggested by the Isaac and Poor results.

All three Monte Carlo studies indicate that an elbow in the stress plot is only significant for the zero error case. Isaac and Poor's calculation of Kruskal's metric determinancy function indicates that the distances produced by the scaling procedures on the present data would correlate about 0.75 with the original dissimilarities.

Cohen and Jones (1974) reported a Monte Carlo study in which a parameter was introduced to simulate a subject's attention wandering among the dimensions of perception during a rating test. Under conditions of 15 points in three dimensions, with 50 percent error in judgment and simulated random attention to only two of the three dimensions of judgment at any one time, Cohen and Jones still achieved 0.75 correlation between estimated and actual distances. They conclude, on the basis of other results, that other Monte Carlo studies (e.g., Wagenaar and Padmos, 1971) have underestimated the seriousness of "underdimensioning" a solution. They recommend that a dimension only be discarded if the investigator is certain it contains only error. They make no mention of the criterion of interpretability for deciding the dimensionality of the solution. Although there have been no responses found in the literature to Cohen and Jones, the ignoring of an "interpretability" criterion seems a serious flaw in their conclusions.

3.7 Summary

This chapter has presented details of test development, scoring procedures, experimental design, and sample selection. Instrument reliability was discussed, and the analytic procedures explicated. The results of the study are presented in the chapter which follows.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the study together with a discussion of their meaning as related to the hypotheses of the study. Section 4.2 presents data which facilitates interpretation of the non-metric orthogonal rotation goodness-of-fit measure (Schonemann and Carroll, 1970; Lingoes and Schonemann, 1974) used in order to estimate the fit of one matrix of scaling results to another. The next section reports data pertaining to the reliability estimates of the instruments used in the study. Section 4.4 contains the results of Kruskal scaling procedures as applied to the group average data for each grade obtained from each of the concept similarity instruments. Section 4.5 reports the Tucker scaling results for each instrument for each grade, the formation of subgroups based upon the Tucker results, and subsequent Kruskal scaling of the subgroup average data. Section 4.6 discusses the personality variables, and differences in these variables among the subgroups formed by the Tucker scaling process. Sections 4.7 and 4.8 parallel 4.5 and 4.6, but for the Carroll analysis. Section 4.9 summarizes the chapter. For compactness of presentation, the short forms summarized in Table II will be used as headings for many of the tables below.

4.2 The Goodness-of-fit Measure

The purpose of this section is to provide data which will help the reader understand the meaning of the goodness-of-fit measure used for comparison of scaling configurations in the present study. The measure will be related to the more common Pearson product-moment correlation coefficient. Schonemann and Carroll (1970) have presented a nonmetric version of the orthogonal Procrustes rotation. The goodness-of-fit measure which they produced was improved by Lingoes and Schonemann (1974). The Lingoes and Schonemann measure of fit has both a symmetric version, in which the rotation of A to B gives the same fit as the rotation of B to A, and a non-symmetric version, in which this is not the case. Both versions are bounded by 0.00 and 1.00.

Lingoes and Schonemann argue that the non-symmetric version, S, is the matrix analogue of a coefficient of alienation, 1.00 minus a squared correlation coefficient. In investigating the interpretation of their goodness-of-fit measure, the following calculations were performed. From the pool of data generated from the main investigation, pairs of matrices were selected whose symmetric goodness-of-fit measures spanned the range from 0.17 to 0.96. All the matrices were 15 by 3 mappings of the concepts under

TABLE II

SUMMARY OF SHORT FORMS USED IN TABLES

Constrained Association-Unscaled Grade 9	CAU9
Constrained Association-Unscaled Grade 12	CAU12
Constrained Association-Scaled Grade 9	CAS9
Constrained Association-Scaled Grade 12	CAS12
Similarity Judgment Grade 9	SJ9
Similarity Judgment Grade 12	SJ12
Semantic Differential Grade 9	SD9
Semantic Differential Grade 12	SD12

investigation. Based upon the value S, a value r was calculated using the formula supplied by Lingoes and Schonemann. For each pair of matrices, A and B, a correlation coefficient was calculated between the values of B, and the values of BHAT, the best rotation of A to fit B. This correlation coefficient was calculated by reforming the 45 entries in each matrix into a vector, and correlating the values in the vectors. As can be seen from Table III, the correspondence between the r derived from S and the correlation coefficient is virtually perfect. It should be noted that, while these calculations offer a benchmark by which to interpret the goodness-of-fit measure, they do not provide any criterion for judging the statistical significance of the S and r values. For the convenience of the reader, both the symmetric coefficient of alienation, SS and the derived r value will be reported for any matrices compared in the remainder of this report. The symmetric coefficient of alienation, SS, is the square root of the non-symmetric version, S.

To assist further in interpretation of the S values, Figure 3 shows the plots for selected dimensions of two pairs of matrices in three dimensions. The arrows go from the position of each point in matrix BHAT to the corresponding position in matrix B. It can be seen from Figure 3 that an SS value of 0.51 (r=0.86) corresponds to a pair of matrices with the majority of points shifting only a small amount. At this level of shift, however, some possibly

TABLE III

RELATIONSHIP BETWEEN GOODNESS-OF-FIT FUNCTION AND CORRELATION COEFFICIENT

Trial	SS	r From S	Corr From Matrices
1	0.17	0.99	0.99
2	0.38	0.92	0.92
3	0.51	0.86	0.86
4	0.62	0.78	0.78
5	0.77	0.64	0.64
6	0.85	0.53	0.52
7	0.96	0.28	0.28

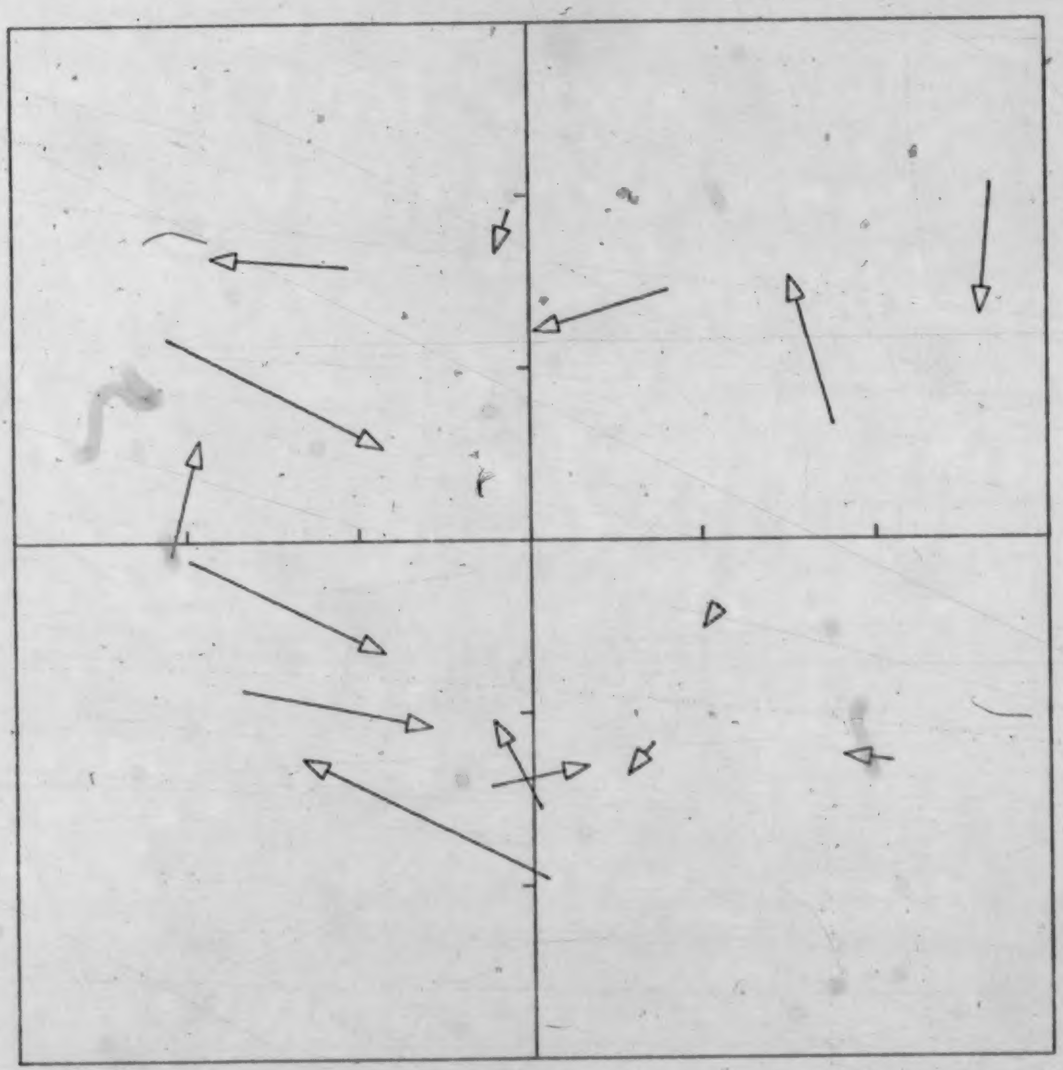


FIG.3 GOODNESS-OF-FIT PLOT FOR S=0.51

DIMENSION 2 (HOR) VS DIMENSION 3 (VER.)

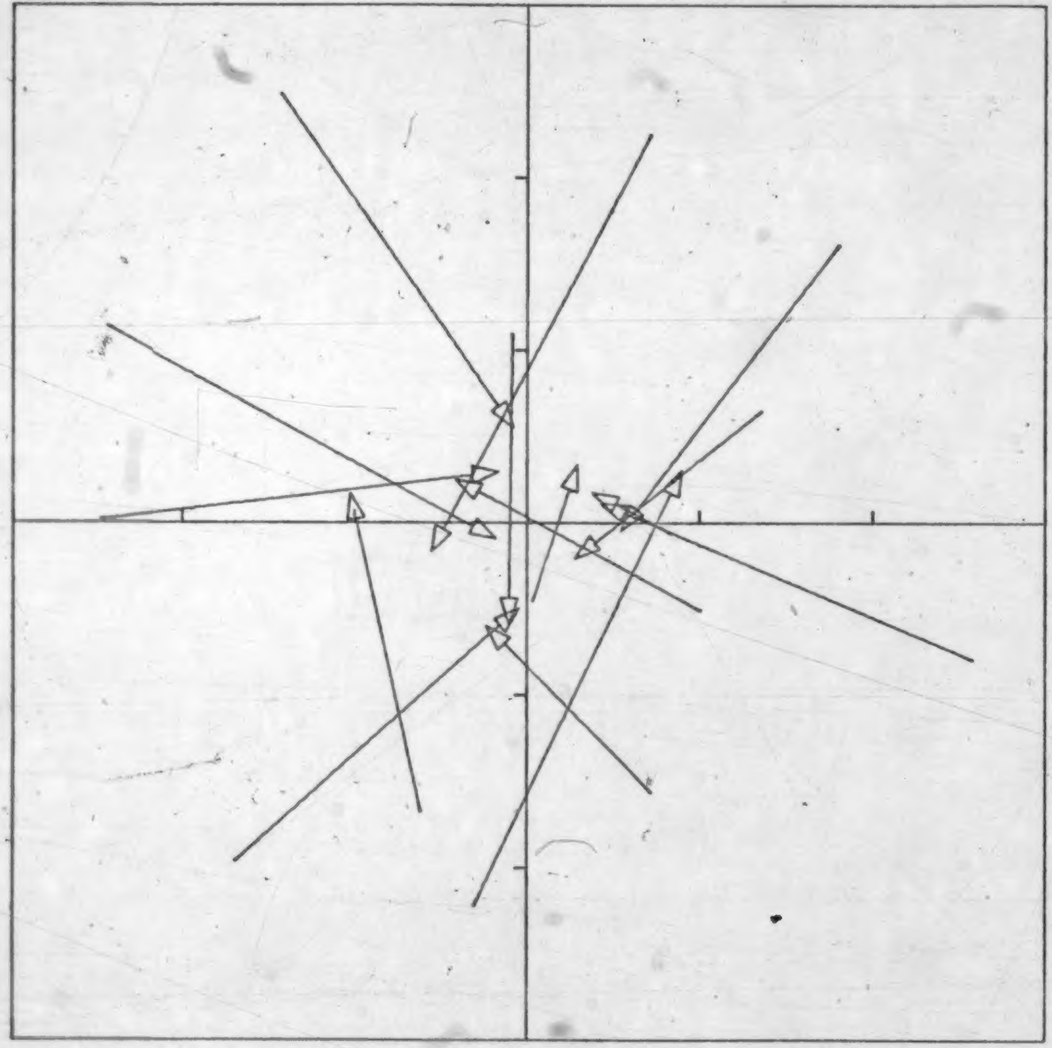


FIG.3 CONTINUED FOR S=0.96
DIMENSION 2 (HOR) VS DIMENSION 3 (VER.)

interpretable trends, such as the shift in points in the lower left hand quadrant, can be seen. Further, an SS of 0.96 (r=0.28) corresponds to large shifts in almost all points. Such ubiquitous shifting would lead to substantial differences in interpretation of the meanings of the dimensions.

4.3 Reliability of Instruments

Reliability estimates for the instruments used in the study are summarized in Table IV.

There are five estimates of reliability of the constrained association test based upon the test-retest data collected from a sample of grade nine subjects not part of the main study. The first estimate listed was obtained by correlating the two vectors of 105 similarities produced by each subject on the two occasions and averaging the individual correlations over the 18 subjects. Since reliabilities for individuals are rarely reported in the literature, the next two estimates are reported for comparison purposes. The similarities were averaged over the subjects, and the two vectors of 105 averaged similarities produced by the group on the two occasions were correlated. This calculation was performed on both the scaled and unscaled similarities. Since the norming was done before averaging, it is coincidence only that the correlation obtained is exactly the same for the scaled and unscaled data.

TABLE IV

SUMMARY OF RELIABILITY ESTIMATES

Constrained Association Test	
Test-Retest (N=18)	
Average Indiv. Corr.	0.33
Group Corr.-Unscaled	0.76
Group Corr.-Scaled	0.76
Kruskal Goodness-of-fit Scaled	0.53
Kruskal Goodness-of-fit Unscaled	0.70
Personal Consistency	
Grade 9 (N=78)	0.46
Grade 12 (N=54)	0.42
Similarity Judgment	
Personal Consistency	
Grade 9 (N=78)	0.56
Grade 12 (N=54)	0.51
Semantic Differential	
Personal Consistency	
Grade 9 (N=78)	0.60
Grade 12 (N=54)	0.64
Similarity Measures	
Average Consistency	
Grade 9 (N=78)	0.20
Grade 12 (N=54)	0.16
Developmental Level Test	
KR-20	
Grade 9 (N=78)	0.45
Grade 12 (N=54)	0.50
Prin.Comp.-Variance on First Factor	
Grade 9 (N=78)	0.38
Grade 12 (N=54)	0.43
Hidden Figures Test	
Split Halves-Correction for Guessing	
Grade 9 (N=78)	0.77
Grade 12 (N=54)	0.78
Split Halves-No Correction	
Grade 9 (N=78)	0.76
Grade 12 (N=54)	0.77
Cognitive Complexity	
Test-Retest	-0.11

The group average data produced by the group on the two occasions were analysed by Kruskal scaling, and rotated to a best fit with each other. The SS values corresponding to the r values in Table IV are 0.85 and 0.71 respectively. A possible explanation for these two reliability estimates being so different might lie in the difference between the average number of responses and the average relatedness indices produced on the two occasions. For the pretest, these values were, respectively, 80.7 and 0.07, while for the posttest, they were 101 and 0.10. The effect of the rescaling procedure would be different in the two cases, adversely affecting the test-retest reliability. Such an increase in fluency on the retest might be attributed to familiarity with the instrument. The two testing occasions were one month apart. The goodness-of-fit r for the unscaled data can probably be taken as a better estimate of reliability than can that for the rescaled data.

No similar test-retest data are available for the older group. Since the reliabilities for other measures reported in Table IV show no substantial differences between the two grade groups, it may be reasonably inferred that test-retest data for grade twelve subjects, if they were available, would not be substantially different from that of the grade nine subjects.

The personal consistency estimates for all three similarity rating tests were calculated as described in Chapter 3. These personal consistency estimates are judged to be satisfactory.

The average consistency measure produced by each subject over the three similarity rating tests produced quite a low consistency estimate. As noted in chapter 3, such an estimate assumes that the three tests are tapping identical cognitive structures. Thus, the estimate is confounded by having to make the same type of assumption as made for the estimates of reliability of the developmental level test. That is, it is not clear whether the correlation coefficient is measuring convergent validity or consistency reliability. Keeping this doubt in mind, it may be hypothesized that the consistency estimate is not out of line with the only other individual reliabilities reported, those for the test-retest on the constrained association test.

As expected, the available methods of estimating reliability of the developmental level test do not produce very high reliability estimates. Possible reasons for these results have been discussed in Chapter 3.

The Hidden Figures Test produced reliability estimates in keeping with expectations based upon values reported in the literature. The correction for guessing seems to have no effect. As an aside, the correlation between the corrected and uncorrected scores was 0.99.

The reliability estimate for the cognitive complexity test reveals it to have an unacceptable error of measurement. This can possibly be explained by the size of the matrix used. Seaman and Koenig (1974) discussed larger matrices (8 by 8 and 13 by 13) than that of the present study. It is possible that, with only six persons to rate, the measure was too dependent upon the persons chosen. For the posttest, subjects were asked to rate the same persons if they could remember who they were, or to rate different persons if they could not. Fourteen subjects reported that they used different people, three that they tried to remember who the persons rated on the first test were, but were not very confident that they had been successful, and only one subject indicated that he was certain he was rating the same persons. Considering the difficulty which grade nine subjects had with the directions and the length of time needed to complete a six by six matrix, it is difficult to see how, given the time constraints of the study, the judgment matrix could have been enlarged. Given that the grade twelve subjects did not experience even a fraction of the difficulty with this test experienced by the grade nine subjects, it might be hypothesized that a similar test-retest for grade twelve subjects would yield higher reliability estimates in this particular test. It is unfortunate that subjects were not available for such a testing.

4.4 Group Average Results

Kruskal scaling was performed on the group average results. The stress values for solutions in from six to two dimensions are reported in Table V. For brevity, the data sets will be referred to by number, as given in Table V. As mentioned above, the purpose of reporting group average solutions is to assess the overall dimensionality of the cognitive structures under investigation. Using the "elbow" criterion as a rough guide, data sets 3,5, and 8 (CAS9, SJ9, and SD12) seem to require a three dimensional solution, data sets 2, 4, and 7 (CAU12, CAS12, and SD9) seem to require a four dimensional solution, while the decision in cases 1 and 6 (CAU9 and SJ12) is not as clear. As noted in chapter 3, Wagenaar and Padmos (1971) maintain that the elbow criterion is applicable only in cases of error free data.

A decision was taken to report only three dimensional solutions in all cases for the following reasons. First, the data are certainly not errorless, and thus, according to the criteria of Isaac and Poor (1974), the stress values for the three dimensional solutions are, in all eight cases, acceptable for a situation in which the data contain errors in the order of 40 percent of the similarity values. In light of the consistency and test-retest reliability estimates reported for the data in the previous section, the assumption of such an error level in the data seems reasonable. Second, the study is an investigation of individual differences in cognitive structures. If subjects are regrouped according to a criterion of similarity, such as are produced by Tucker or Carroll scaling, it seems reasonable to expect a subgroup to

TABLE V

STRESS 1 VALUES FOR FULL GROUP AVERAGE KRUSKAL SOLUTIONS

	Dimension				
	6	5	4	3	2
Data Set					
1. Constrained Association Unscaled Grade 9 (N=78)	4.8	5.0	4.9	8.1	11.4
2. Constrained Association Unscaled Grade 12 (N=54)	4.9	5.0	5.6	10.2	13.4
3. Constrained Association Scaled Grade 9 (N=78)	4.8	5.0	5.0	6.2	14.0
4. Constrained Association Scaled Grade 12 (N=54)	5.0	5.0	6.1	10.8	15.8
5. Similarity Judgment Grade 9 (N=78)	5.0	5.0	5.0	6.1	14.1
6. Similarity Judgment Grade 12 (N=54)	4.9	4.9	5.1	7.8	15.5
7. Semantic Differential Grade 9 (N=78)	4.7	4.8	5.0	12.7	16.7
8. Semantic Differential Grade 12 (N=54)	4.9	4.9	4.9	6.2	11.9

be more homogeneous than the total sample. A possible reason for requiring a four dimensional solution would occur in a situation in which part of the sample based judgments on, for example, dimensions 1, 2, and 3, while another part of the sample based judgments upon, say, dimensions 1, 2, and 4. Analysis of subgroups in such a case would produce three dimensional solutions, with two of the dimensions similar, but the third one different. Such an occurence in the present study cannot be ruled out. Third, based upon expectations from the pilot work, three dimensional solutions would be more readily interpretable than four dimensional solutions in this study. Fourth, data sets 2, 4, 6, and 8 from Table V are grade twelve data. Because of the smaller sample size in grade twelve, these data sets may be expected to contain more error of measurement than the larger grade nine sample data. As will be reported in detail later, this point is supported by stress values for scaling solutions of smaller subgroups in general. This would account for the relatively high stress values found in the CAU12, CAS12, and SJ12 data. Fifth, and in partial contradiction to the previous statement, a case can be made for three dimensional solutions based upon the reliability measures of Table IV. Based upon the personal consistency measures for the three tests, the grade nine sample had less error in the constrained association and similarity judgment tests, while the grade twelve sample had less error in the semantic differential test. Although the significance level of the consistency measure cannot be estimated from the data, and the difference between the grades is small, the trend indicated would predict higher stress values for cases 2, 4, 6, and 7, and lower stress values for cases 1, 3, 5, and 8. Sixth, as will be reported in section 4.7, one of the results of the Carroll scaling analysis is a correlation between the scaling solution and the raw data input for each subject. The average correlation between data and solution did not improve sufficiently when moving from three to four dimensions to warrant reporting of four dimensional solutions for the Carroll scaling analysis.

The dimensions revealed by Kruskal analysis are arbitrary, and therefore solutions for the different data sets cannot be compared directly with each other. The solutions must be rotated to some common target before comparisons are possible. Since Carroll and Chang (1970) maintain that the dimensions found in their analysis are meaningful, one of the group average results from the Carroll analyses was arbitrarily chosen as the common target to which to rotate the Kruskal results of the eight data sets. The solution chosen was the grade nine similarity judgment solution. Table VI reports the three dimensional Kruskal solutions for the eight data sets rotated to a common target. Again, because of the arbitrary nature of the orientation, it should be noted as an aside that no comment can be made concerning the relative importance of each dimension based upon the size of the average loading on each

TABLE VI
KRUSKAL SOLUTION OF FULL GROUP DATA ROTATED TO SAME TARGET CAU9, CAU12, CAS9, CAS12, SJ9, SJ12

Concepts	Dimensions					
	1	2	3	1	2	3
Conc	-0.11	0.02	-0.35	-0.05	-0.14	0.21
Disc	0.13	-0.33	-0.29	0.20	-0.12	-0.23
Evid	-0.23	-0.21	-0.11	-0.16	-0.20	-0.15
Expt	0.14	0.03	-0.13	0.13	-0.10	0.03
Expl	0.01	-0.13	0.08	-0.08	0.18	-0.19
Fact	-0.31	-0.14	-0.05	-0.27	-0.12	-0.15
Hypo	0.09	0.28	0.16	0.08	0.11	0.12
Imag	0.15	0.31	0.51	0.07	0.44	0.39
Inte	-0.02	0.33	-0.08	-0.04	0.30	0.02
Inve	0.18	-0.03	-0.12	0.12	-0.24	0.01
Law	-0.51	-0.23	0.07	-0.36	-0.31	-0.02
Proo	-0.22	-0.22	-0.10	-0.19	-0.17	-0.12
Puzz	0.49	0.17	0.08	0.50	0.11	0.02
Ques	0.29	0.07	0.13	0.22	0.16	-0.07
Theo	-0.09	0.10	0.20	-0.14	0.09	0.13
Conc	-0.07	0.07	-0.38	-0.05	0.15	-0.22
Disc	0.10	-0.26	-0.40	0.20	-0.28	0.02
Evid	-0.23	-0.21	-0.05	-0.13	-0.21	-0.15
Expt	0.19	-0.10	-0.05	0.11	-0.03	-0.10
Expl	-0.09	-0.12	-0.11	-0.08	-0.03	0.24
Fact	-0.32	-0.18	-0.04	-0.26	-0.23	-0.00
Hypo	0.12	0.27	0.15	0.07	0.16	0.03
Imag	0.07	0.22	0.56	0.09	0.51	0.25
Inte	-0.03	0.35	-0.07	-0.07	0.25	0.11
Inve	0.20	-0.16	-0.03	0.12	-0.13	-0.20
Law	-0.40	-0.34	0.19	-0.38	-0.17	-0.15
Proo	-0.23	-0.22	-0.06	-0.16	-0.14	-0.16
Puzz	0.50	0.15	0.16	0.46	0.09	0.05
Ques	0.28	0.16	-0.05	0.21	0.02	0.17
Theo	-0.09	0.12	0.19	-0.14	0.05	0.13
Conc	-0.26	0.01	-0.31	-0.19	-0.18	0.05
Disc	0.02	-0.10	-0.34	0.10	-0.04	-0.23
Evid	-0.19	-0.23	-0.16	-0.17	-0.15	-0.18
Expt	0.27	-0.09	-0.07	0.21	-0.08	-0.01
Expl	-0.23	0.00	-0.06	-0.17	0.04	-0.11
Fact	-0.30	-0.27	-0.18	-0.28	-0.22	-0.24
Hypo	0.21	0.31	0.19	0.07	0.18	0.28
Imag	0.21	0.52	0.39	0.24	0.54	0.27
Inte	-0.15	0.35	-0.07	-0.15	0.27	-0.07
Inve	0.22	-0.15	-0.02	0.17	-0.16	0.03
Law	-0.39	-0.33	0.09	-0.45	-0.20	-0.09
Proo	-0.24	-0.27	-0.19	-0.20	-0.25	-0.15
Puzz	0.55	0.09	0.22	0.55	0.09	0.14
Ques	0.38	0.01	0.24	0.35	0.09	0.04
Theo	-0.09	0.13	0.27	-0.09	0.08	0.25

TABLE V1 (CONT.)
KRUSKAL SOLUTION OF FULL GROUP DATA
ROTATED TO SAME TARGET SD9, SD12

Concepts	Dimensions					
	1	2	3	1	2	3
Conc	-0.12	0.08	-0.12	-0.28	-0.02	0.06
Disc	0.05	-0.27	-0.11	0.03	-0.13	-0.26
Evid	-0.06	-0.21	-0.18	-0.20	-0.27	-0.26
Expt	-0.03	-0.03	-0.30	0.23	-0.38	-0.07
Expl	0.09	-0.04	-0.04	-0.25	0.05	-0.06
Fact	-0.12	-0.21	-0.10	-0.17	-0.12	-0.16
Hypo	0.09	0.34	0.21	0.06	0.39	0.24
Imag	0.08	0.02	0.21	0.06	0.10	0.14
Inte	0.03	0.18	0.07	0.02	0.41	-0.03
Inve	-0.27	0.04	0.04	0.17	-0.11	-0.16
Law	-0.16	-0.16	0.06	-0.06	-0.19	-0.00
Proo	-0.06	-0.20	-0.13	-0.20	-0.21	-0.19
Puzz	0.37	-0.01	0.05	0.48	0.08	0.05
Ques	0.02	0.12	0.32	0.15	0.09	0.41
Theo	0.09	0.35	0.01	-0.05	0.31	0.30

dimension.

In chapter 3, it was noted that the dimensions interpreted as time and certainty were confounded in the pilot work. This problem, as expected, has persisted into the main study. In attempting to label the different dimensions, relatively subtle differences in loadings of the concepts have been focused upon in order to create distinguishable labels. For example, the main distinguishing feature of a dimension labelled "temporal" rather than certainty is the presence of a high loading for the concept "conclusion". Similarly, the distinguishing feature of a dimension labelled "certainty" rather than "creativity" is high loadings for the concepts "puzzle" and "question" rather than "imagination" and "hypothesis". As will be seen, these various dimensions are rarely clearcut. The terms "law", "fact", "evidence", and "proof" tended to cluster quite closely together on most dimensions. Thus, they were not useful for distinguishing dimensions. The concepts at the opposite ends of the continua from these terms, e.g., those which were "less certain", "earlier", or "more creative", were usually the best basis for labelling the dimensions. The label "theoretical vs. practical" was employed on those occasions when "law" or "theory" was close to "hypothesis" and opposed to "conclusion", "fact", or "discovery". A summary of interpretations given the Kruskal configurations is presented in Table VII.

For the unscaled grade nine constrained association

TABLE VII

SUMMARY OF DIMENSION INTERPRETATIONS FOR KRUSKAL SOLUTIONS OF FULL GROUP DATA

Data Set	Dimension 1	 2	 3
CAU9	1	2	4
CAU12	1	2	0
CAS9	1	2	3
CAS12	1	2	0
SJ9	1	2	1
SJ12	1	2	3
SD9	1	2	0
SD12	1	3	0

0 - No clear interpretation
1 - Certainty
2 - Creativity
3 - Theoretical-practical
4 - Temporal

results (CAU9), the first dimension has been labelled "certainty". The concepts "puzzle" and "question" are opposed to the cluster of "law", "fact", "evidence", and "proof". The concepts "conclusion" and "explanation" do not load highly on this dimension. Dimension two, which clusters "hypothesis", "imagination", and "interpretation" opposite "discovery", "law", and "proof" has been labelled "creativity". The third dimension has been labelled "temporal" because of the high loading of the concept "conclusion". "Conclusion " has been chosen as a relatively clearly "temporal" rather than "certainty" concept.

In the second set of results, the grade twelve unscaled constrained association (CAU12), the first two dimensions have been labelled "certainty" and "creativity", but the third dimension has been left unlabelled because of the puzzling coupling of "conclusion" with "imagination" and "hypothesis" in opposition to "discovery", "evidence", and "explanation".

The effect of the rescaling of the grade nine data, CAS9, is most noticeable in the third dimension, which has been labelled "theoretical-practical" rather than "temporal". The first two dimension labels remain the same as for the CAU9 data. The third dimension of CAU9 was labelled as it was because of the coupling of "law" with "theory", in opposition to "discovery" and "conclusion".

The rescaling of the grade twelve data (CAS12) had no effect on the labels of the first two dimensions, but the third dimension, although quite different from that of the CAU12 data, still remains puzzling and unnamed.

The grade nine similarity judgment dimensions were labelled "certainty", "creativity", and "certainty", respectively. Dimensions one and three are correlated 0.54. No other label was deemed appropriate for dimension three. The corresponding dimensions for the grade twelve sample (SJ12) were labelled "certainty", "creativity", and "theoretical-practical".

The semantic differential data seemed to require considerable stretching of the rules established for labelling the first six matrices reported. For example, in the grade nine data (SD9), the first dimension was labelled certainty despite the fact that "question" did not occupy, as in the first six data sets, its usual position quite close to "puzzle". Similarly, dimension two was labelled "creativity" despite the absence of a high loading for "imagination". The third dimension was not labelled. In the grade twelve data (SD12), the first dimension was labelled certainty, but the second dimension seemed closer to the criteria for "theoretical-practical" than "creativity" because of the large loading for "experiment". Again, it was not possible to name the third dimension.

In summary, a few limited generalizations about the concept perceptions as indicated by the Kruskal solutions can be made. First, the dimensions of "certainty" and "creativity" (with one exception) seemed relatively stable throughout the eight sets of data. The third dimension varied enough that it seemed to require different labels for the different sets of data. There are no obvious patterns across either similarity measures or grades for the meanings assigned to dimension 3. The concept "imagination" was, in general, not as isolated for the grade twelve sample as it was for the grade nine sample. Because of its relative proximity to "hypothesis" and "theory", the concept "imagination" could perhaps be viewed as more accepted as part of the scientific reasoning process. This in turn could reflect a more mature appreciation of the role of imagination in the work of the scientist. The concept "discovery" appeared not to be treated in the sense of discovery of a theory, but more in the sense of invention. When it played a significant role in the definition of a dimension, it was usually grouped with "law" and "conclusion" rather than "theory". Finally, the four concepts "law", "fact", "proof", and "evidence" were quite consistently clustered together. A main purpose of this study was to search for construct validity of cognitive structure. It was hypothesized that such validity would be achieved by production from the data of scaling configurations interpretable in the context of the 15 example concepts chosen for examination, and by convergence of these configurations produced from the data of different similarity rating tests to the same solution. The results presented in Table VII and their discussion have provided the first part of this evidence for construct validity. The results presented next address the second half of the construct validity of cognitive structure, discriminant validity.

Further detailed analysis and reporting of the cognitive structures of the various subgroups formed in this study could amount to information overload for the reader, and because of the volume of data involved would distract from discussion of the more important questions of convergence and individual differences. Reporting of the structures will be confined to the use of the goodness-of-fit measure unless, in a particular case, a point pertinent to the main hypotheses (convergence and individual differences) of this investigation can be made by reference to the concepts themselves. The example concepts chosen are not themselves central to the hypotheses of the study.

Results pertaining to the convergent and discriminant validity of the three tests are summarized in Table VIII. As stated above, "SS" is the symmetric goodness-of-fit measure between the rotated matrix and the target matrix, and "r" is the corresponding correlation (see Table III). The top section of the table reports the effect of rescaling the constrained association data to minimize effects of differences in fluency of response. These data do not directly address the issue of convergence, but are of interest in terms of the behaviour of the constrained association data. Although, as reported in the previous

TABLE VIII

GOODNESS-OF-FIT MEASURES FOR KRUSKAL SOLUTIONS OF FULL GROUP AVERAGE DATA

Rotated Matrix	Target Matrix	SS	r
Effect of Scaling			
CAU9	CAS9	0.35	0.94
CAU12	CAS12	0.23	0.97
Convergent Validity (Grade 9)			
CAS9	SJ9	0.42	0.91
CAS9	SD9	0.78	0.62
SJ9	SD9	0.77	0.64
Convergent Validity (Grade 12)			
CAS12	SJ12	0.45	0.89
CAS12	SD12	0.74	0.76
SJ12	SD12	0.64	0.76
Grade Differences			
CAS9	CAS12	0.63	0.78
SJ9	SJ12	0.38	0.92
SD9	SD12	0.71	0.70

section, the labels for the dimensions were not consistent for the scaled and unscaled cases, the goodness-of-fit measures indicate little difference in the matrices. It can be tentatively concluded that, for the full group average data, rescaling has little effect.

The next two sections of Table VIII summarize the evidence for the convergent validity of the instruments. As such, they address one of the major hypotheses of the study. For both the grade nine and grade twelve data, there seems to be good convergence between the constrained association and the similarity judgment results, with substantially poorer convergence for the semantic differential results with the other instruments. The poorer convergence of the grade nine semantic differential results compared to that of the grade twelve classes may be attributed to the greater difficulty experienced by the grade nine subjects on the semantic differential test.

The bottom section of Table VIII summarizes data which indirectly addresses the discriminant validity of the instruments. The assumption which must be made in interpreting these goodness-of-fit measures as discriminant validity indices is that the cognitive structures of grade nine and twelve subjects are actually different with respect to these concepts. According to Campbell and Fiske (1959), the goodness-of-fit measures in the bottom section of the table should be substantially lower than those in the middle two sections in order to provide positive evidence for construct validity. As can be seen, this is not the case. However, as pointed out in chapter 3, we have no way of determining the extent to which the cognitive structures of grade nine and twelve subjects should differ. Because subjects separated by grade may not differ substantially in cognitive structure does not rule out the possibility that there exist other variables along which subjects may be grouped in order to isolate differing cognitive structures. The individual scaling sections of this investigation are addressed to this issue.

The convergence and discrimination among the scaling configurations have addressed the hypothesis of construct validity of cognitive structure. Convergence between constrained association and similarity judgment was quite high, with the semantic differential instrument yielding solutions which did not converge as well. It may be hypothesized that the semantic differential instrument did not provide enough bipolar scales to cover all the dimensions of semantic space along which subjects were rating concepts as revealed by the other two instruments. Whether or not the instrument could be modified to provide better convergence with the other two instruments is a matter for further investigation.

4.5 Tucker Scaling Results-Cognitive Structures

The Tucker scaling procedure consists of a principal components analytic step, a decision on grouping of subjects by the investigator, and a Kruskal scaling step. Table IX presents the percentage variance accounted for by the first nine factors for each of the eight data sets taken separately. Since the last six data sets were all scaled to mean 10.0 and standard deviation 2.0, the first factor in these cases is a mean factor. In these cases, the first factor was not included in the varimax rotation to simple structure. All subject loadings on this factor were, within rounding error, equal. In the first two data sets the first factor is probably also best interpreted as a mean factor. However, since the percentage variance is substantially lower in this case, and since subject loadings were not equal on the first factor, the factor was retained for the first two data sets. Percentage variance for the remaining factors in the last six cases is expressed as a percentage of variance remaining excluding the first factor. This accounts for the fact that the percentage variance accounted for in the table exceeds 100 percent. For the unscaled data, the first two sets, the first factor was retained for rotation. Scree tests perfomed on the percentage variance suggest in some cases (e.g., data set 8) how many factors should be retained, but in most cases the decision is not clearcut. Since the object of the rotation is to form groups of subjects, it was arbitrarily decided that four groups would be a reasonable number to attempt to form on the basis of each data set. For this reason, four factors were retained for varimax rotation. For the first two data sets,

TABLE IX

UNROTATED TUCKER FACTORING-PERCENTAGE TOTAL VARIANCE ACCOUNTED FOR BY FIRST NINE FACTORS FOR EACH DATA SET SEPARATELY

	Factors								
	1	2	3	4	5	6	7	8	9
Data set									
1. CAU9	55.5	5.8	3.1	2.8	2.5	2.4	2.1	2.0	1.9
2. CAU12	62.7	5.1	3.3	2.4	2.3	2.2	1.9	1.6	1.5
3. CAS9	97.2	8.0	7.4	6.2	5.3	4.8	4.7	4.3	3.9
4. CAS12	97.1	8.2	6.6	6.5	5.9	5.8	5.3	4.6	4.2
5. SJ9	97.3	7.9	6.1	5.2	4.4	4.0	3.6	3.5	3.3
6. SJ12	97.2	7.6	5.5	5.4	5.0	4.5	4.2	3.8	3.7
7. SD9	96.5	7.8	6.3	5.6	5.3	5.1	4.5	4.2	3.9
8. SD12	96.6	9.3	8.8	7.4	5.7	5.5	4.9	4.6	4.2

Data sets 1 and 2, percentages calculated including first factor.
Data sets 3 to 8, percentages calculated excluding first factor.

factors one to four were used, while for the remaining data sets, factors two to five were used. Loadings of the subjects (Tucker's V - loading of people on principal vectors) on the unrotated factors are presented in Tables XXIII to XXX in Appendix B.

The loadings of Tables XXIII to XXX were rotated to simple structure by the varimax rotation. Results are reported in Tables XXXI to XXXVIII in Appendix B. An objective method of deciding group membership on the basis of these loadings was devised according to the following scheme. If a subject loaded greater than 1.00 on more than one factor, he was not placed in a group. If a subject's highest loading was less than one and one-half times as large as his second highest loading, he was not placed in a group. If a subject loaded less than 0.50 on all four factors, he was not placed in a group. Subject to these rules, subjects were grouped according to their highest loading. By this method, mutually exclusive but not exhaustive groups were formed. Group membership is presented in Table X. Overall, 61 percent of subjects were assigned to groups. It is probable that those excluded from groups produced data which differed substantially from the group average. Such subjects may have contributed a relatively large proportion of what was labelled error in the data. As could be predicted from the size of the goodness-of-fit measures between instruments, there are no consistencies of group membership across the four groupings at each grade

TABLE X

SUMMARY OF GROUP MEMBERSHIP BY TUCKER SCALING

Group	N	Subject ID's
CAU9 Grp 1	20	2,11,19,35,36,52,56,58,61,62,64,65,66,67,68 69,73,76,77,78
2	8	1,16,20,24,30,40,55,59
3	11	32,34,37,39,42,43,46,48,50,53,63
4	8	4, 9,13,23,28,38,47,54
CAU12 Grp 1	6	11,20,23,39,41,47
2	8	3, 8,14,22,25,30,38,50
3	5	16,21,24,44,49
4	17	4, 7, 9,12,13,17,18,26,27,28,31,34,36,40,42 48,53
CAS9 Grp 1	9	2, 5,26,44,46,48,60,63,70
2	10	17,18,19,22,30,67,71,73,75,78
3	9	3,11,23,28,36,56,57,58,64
4	14	1, 6,16,25,29,34,37,39,40,42,43,49,62,74
CAS12 Grp 1	10	4, 5,10,14,18,27,28,31,34,44
2	9	1, 8,13,16,21,25,35,36,50
3	8	6, 9,20,23,26,40,52,53
4	8	3,11,24,39,43,46,49,54
SJ9 Grp 1	11	1, 8,15,33,43,47,49,51,56,69,78
2	10	18,27,28,29,42,54,55,58,68,70
3	12	3, 6, 9,21,30,41,45,46,73,74,75,76
4	11	4,13,19,23,32,34,35,39,50,53,67
SJ12 Grp 1	7	4, 7, 9,18,26,48,54
2	7	8,14,16,24,43,47,52
3	11	2,15,20,22,25,28,31,32,34,38,44
4	8	6,11,12,17,27,49,51,53
SD9 Grp 1	15	2, 8,11,20,36,47,52,56,57,60,63,64,69,72,77
2	9	3,12,21,27,28,37,48,50,71
3	13	5, 6,22,26,38,54,55,58,59,62,65,67,75
4	9	14,18,19,30,31,35,49,51,74
JD12 Grp 1	10	4, 7,11,18,20,26,30,47,51,52
2	10	5, 9,15,21,29,40,42,44,50,54
3	9	2, 3, 6,13,24,27,39,46,49
4	8	1, 8,16,23,25,28,31,41

level. Such groupings of subjects together based upon similarity of responses within more than one test would have offered strong evidence for convergent validity of the instruments.

Group average similarity matrices were formed for each of the subgroups reported in Table X. Kruskal scaling of the 32 average matrices was performed. Stress values for these Kruskal solutions for from six through two dimensions are reported in Table XI. The increase in stress values from the large group average scaling (see Table V) to the subgroup scaling must be attributed to a corresponding increase in error in the data. This is despite the fact that, on the average, only 61 percent of the subjects passed the requirements for group membership based upon the Tucker scaling results. Even though, presumably, the most stable 61 percent of the data were retained, the smaller size of the subgroups compared to the full groups must have increased the sampling error of the average similarity ratings. A larger group whose similarities were being averaged would allow the errors of measurement in individual similarities to "smooth out". The patterns of stress values in Table XI may be interpreted on the basis of Wagenaar and Padmos' results (1971) as indicating a high percentage of error in the data. While some of the stress values are somewhat higher or lower than others for the same number of dimensions (e.g., constrained association unscaled grade twelve group 4 three and four dimensions; semantic

TABLE XI
STRESS VALUES FOR KRUSKAL SCALING OF TUCKER SUBGROUP AVERAGE MATRICES

		Dimension				
		6	5	4	3	2
CAU9	Group 1	10.1	10.1	13.8	19.9	27.4
	2	8.2	10.1	13.5	18.2	26.7
	3	11.2	13.1	16.3	21.8	30.1
	4	10.1	12.0	15.2	20.0	28.7
CAU12	Group 1	9.0	10.4	14.8	18.8	29.0
	2	9.2	12.2	15.7	20.8	30.2
	3	8.5	11.4	14.3	20.9	29.0
	4	7.7	9.1	11.8	16.5	27.3
CAS9	Group 1	9.3	9.8	13.7	19.6	28.8
	2	7.5	10.4	13.5	17.4	27.0
	3	8.0	9.1	12.6	18.3	26.1
	4	8.7	10.8	12.5	17.4	28.7
CAS12	Group 1	9.0	10.3	13.3	20.1	27.3
	2	6.9	9.5	12.6	17.9	27.1
	3	6.6	9.2	13.4	18.2	27.3
	4	10.1	11.8	15.5	19.8	28.8
SJ9	Group 1	10.7	13.5	16.5	21.9	31.0
	2	11.3	12.5	15.9	21.4	29.6
	3	10.8	13.2	17.2	22.5	30.1
	4	10.5	13.1	16.4	21.9	30.9
SJ12	Group 1	9.0	11.1	14.7	21.3	31.1
	2	9.3	11.7	14.6	20.1	28.9
	3	7.7	11.4	14.4	19.6	29.6
	4	10.9	11.9	16.6	22.3	31.1
SD9	Group 1	7.3	10.4	15.7	21.0	30.5
	2	10.9	13.1	17.1	23.0	31.0
	3	9.8	12.1	15.6	21.2	28.5
	4	9.8	11.7	15.4	20.5	31.6
SD12	Group 1	7.8	11.3	14.7	19.1	26.6
	2	9.8	12.9	16.8	21.5	30.7
	3	10.7	11.8	15.5	20.6	30.3
	4	10.3	11.9	15.1	20.1	30.3

differential grade nine group 2, three and four dimensions), there seem to be no substantial reasons for reporting four dimensional solutions instead of three dimensional solutions. Therefore, the three dimensional Kruskal scaling results for the 32 subgroups are reported in Table XXXIX in Appendix B. These solutions have been rotated to the best fit with their respective group averages.

These Kruskal scaling results were rotated by the nonmetric orthogonal Procrustes rotation to each other in all possible combinations of the large group average and the four subgroup averages within each of the eight data sets. The resulting goodness-of-fit measures are presented in Table XII. In this and similar subsequent tables, "group 0" refers to the full group of grade nine (N=78) or grade twelve (N=54) subjects. From the goodness-of-fit measures it can be seen that in general the Tucker scaling method has identified different patterns of responses to the concept relationship tasks. The subgroup patterns tend to bear little resemblance to each other, and almost no resemblance to the total group average results. Note that the value r based upon SS, the symmetric coefficient of alienation, cannot be negative. Detailed discussion of the differences in perceptual patterns will not be entered into until the personality variables of the subgroup members are discussed in the next section. Analysis of the structural patterns of the 32 subgroups without reference to the personality variables would not address the hypotheses of this

TABLE XII

GOODNESS-OF-FIT AMONG TUCKER SUBGROUP SOLUTIONS AND WITH RESPECTIVE FULL GROUP SOLUTIONS

		Grade 9 Groups					Grade 12 Groups				
		0	1	2	3	4	0	1	2	3	4
CAU Grp	0		18	15	14	15		28	29	28	17
	2	98		44	49	51	96		33	31	37
	2	99	90		57	52	96	94		38	40
	3	99	87	82		57	96	95	92		45
	4	99	86	85	82		98	93	92	90	
CAS Grp	0		12	22	22	12		25	18	15	26
	1	99		41	31	48	97		39	56	49
	2	98	91		35	41	98	92		49	49
	3	98	95	93		41	99	83	86		55
	4	99	85	93	91		96	87	87	84	
SJ Grp	0		26	10	17	22		19	17	10	16
	1	97		42	36	35	98		38	58	62
	2	99	91		37	61	99	92		29	34
	3	99	93	93		48	99	82	96		53
	4	98	93	80	88		99	79	94	85	
SD Grp	0		23	32	23	38		22	13	19	29
	1	97		56	33	46	98		37	42	35
	2	95	83		45	51	99	93		57	53
	3	97	95	89		36	98	91	80		46
	4	92	89	86	93		96	94	85	89	

Below diagonal - SS; above diagonal - r
Decimals omitted

investigation. At this point in the discussion, it is possible to conclude that the technique of Tucker subgroup formation has isolated subgroups whose Kruskal configurations have very poor fits with each other and with the full group configuration. Generalization from these data to individual differences in cognitive structure as hypothesized will be left until the discussion of the personality variables of the subgroups which follows next.

4.6 Tucker Scaling Results-Personality Variables

The proper procedure to follow in searching among the subgroup members for differences in the personality variables would be a multivariate analysis of variance procedure. This procedure was attempted, but the inverses of the matrices of personality variables could not be calculated because of high correlations among the personality variables. That is, the determinant of the matrix approached zero. The problem can be avoided by deletion of one of the redundant variables. Since in the present data the correlations under consideration were not exactly equal to 1.00, it would make a difference which variable were discarded. Rather than risk deletion of an important variable, one way analysis of variance was chosen as the analytic technique. Because of the danger of finding a significant difference by chance alone, all tests of significance were at the 0.01 level. A summary of analysis of variance results is reported in Table XIII. The first

TABLE XIII
ANALYSIS OF VARIANCE-PERSONALITY VARIABLES AMONG TUCKER SUBGROUPS

	CAU		CAS		SJ		SD	
	F	p	F	p	F	p	F	p
Grade 9								
Age	0.5	.68	1.1	.38	0.6	.60	0.2	.92
Sex	0.2	.87	2.3	.09	0.1	.96	0.6	.63
I.Q.	0.7	.54	0.1	.94	1.8	.17	1.3	.31
Achievement	0.4	.78	1.4	.27	1.6	.20	0.8	.53
Hidden Figures	1.8	.16	0.3	.86	0.4	.74	0.5	.71
Developmental Level	1.9	.14	0.6	.62	0.4	.77	1.0	.41
Cognitive Complexity	0.3	.85	2.5	.07	1.1	.38	0.4	.78
Consistency-SJ	0.1	.97	0.3	.86	0.2	.88	0.3	.85
Consistency-SD	2.2	.10	0.8	.50	0.0	.99	0.1	.96
Consistency-CA	1.4	.27	1.2	.34	0.9	.44	1.4	.26
Total responses-CA	5.2	.004	1.0	.39	0.3	.84	0.1	.94
Internal responses-CA	6.7	.001	4.4	.010	1.8	.16	1.8	.15
Fraction internal-CA	4.5	.008	3.9	.016	2.3	.10	1.9	.15
Avg.relatedness index	16.6	<.001	5.2	.004	1.1	.36	1.0	.41
Personal Consistency	1.2	.31	0.4	.78	0.6	.64	0.8	.49
Grade 12								
Age	1.7	.20	1.9	.16	1.2	.31	1.6	.20
Sex	0.1	.98	1.2	.33	0.9	.45	1.8	.17
Achievement	2.7	.06	0.2	.88	0.8	.53	1.9	.14
Hidden Figures	1.3	.30	0.3	.86	2.0	.14	0.2	.88
Developmental Level	0.4	.74	1.4	.27	2.5	.08	0.4	.74
Cognitive Complexity	1.5	.25	1.5	.25	0.1	.95	2.1	.12
Consistency-SJ	1.2	.33	0.4	.79	2.3	.10	1.8	.16
Consistency-SD	2.5	.07	0.2	.93	0.9	.48	0.5	.72
Consistency-CA	1.3	.29	1.3	.30	2.1	.13	0.3	.82
Total responses	1.2	.34	0.7	.59	0.8	.49	0.7	.57
Internal responses-CA	18.2	<.001	2.0	.13	0.6	.64	0.3	.81
Fraction internal-CA	10.4	<.001	2.1	.12	0.8	.51	0.1	.96
Avg.relatedness index	12.9	<.001	2.1	.12	0.6	.62	0.3	.81
Personal Consistency	1.7	.18	2.5	.08	0.9	.43	0.2	.88

Notes:

1. Three decimals reported for significant or near significant differences only.
2. df - groups = 3 for all data sets
3. df - error

CAU9 - 43	CAU12 - 32
CAS9 - 38	CAS12 - 31
SJ9 - 40	SJ12 - 29
SD9 - 42	SD12 - 33

four variables in the table are self explanatory. The next three were discussed in section 2.5. The four consistency measures were discussed in sections 3.2 and 3.3. The remaining variables pertain to fluency on the constrained association test. "Total responses" is the total number of responses produced by the subject. "Internal responses" is the total number of responses consisting of words from the original list of 15 stimulus concepts. "Fraction internal" is "internal responses" divided by "total responses". Average relatedness index measures the degree of cohesiveness of the pool from which responses are drawn. The finding of significant differences in personality variables among subgroups would indicate that the subgroups who have already given evidence of differences in cognitive structure also differ on personality variables. It was a hypothesis that differences in cognitive structure could be related to differences in personality variables. The only significant differences found were on those variables generated internally by the constrained association test among the groups formed from the unscaled constrained association data. Such a difference, while interesting and not unexpected, is not of major theoretical importance. It is of interest, however, that the differences in fluency variables found for the unscaled constrained association data did not persist to the scaled data. It may be concluded at this point that the rescaling of relatedness indices, although it does not, according to the results reported in Table VIII, make any appreciable difference to the full group average Kruskal results, does avoid the formation of subgroups based primarily on fluency. Whether or not such formation is desired is a matter for judgment in the context of the particular investigation under consideration. Systematic checking of about one-third of the 96 dimensions of the 32 scaling solutions revealed only the occasional interpretable dimension.

The lack of significant differences among the theoretically important personality variables and the lack of suitable interpretations for the scaling solutions can be traced to several possible reasons. First, error in the concept relationship data, error of measurement in the personality variable measures, and high stress for the scaling solutions may have combined to obscure any potentially significant results. Second, the personality variables may not be related to differences in cognitive structure. Thus, members of the subgroups may have widely different cognitive structures, with the resultant average being uninterpretable. Third, if the perceptions of the subjects were constrained by the "right answers", as they possibly might have been in the Kass (1971) study, then the Tucker scaling may have loaded those subjects close to the group average in perception to approximately the same extent on all dimensions. Thus, according to the criteria for subgroup formation such subjects would not be included in any of the subgroups. As a result, the Tucker process may be isolating only those subjects who deviate from the group average substantially. The data of subjects who deviate from the group average a great deal may be largely random error.

The lack of interpretability of the Kruskal solutions for the Tucker subgroups suggests that the Kruskal technique has not functioned productively in the subgroup data analysis. Since the Kruskal technique did function successfully on the large group data, it seems reasonable to conclude that, with a smaller sample size in the subgroups, the sampling error was relatively larger, and the percent error in the data became too large for the revealing of meaningful dimensions. If this is the case, then these results suggest that, in fact, the Wagenaar and Padmos criteria for acceptable stress may be too lenient.

Doubt has been cast upon the operation of the Tucker technique for the formation of subgroups, and upon the Kruskal technique on subgroup average data. It was a hypothesis of this study that differences in cognitive structure would be connected to differences in personality variables. Based upon the results reported thus far, it would appear that it will not be possible to address this hypothesis in the present study. It has not been established that the Tucker technique is forming subgroups on the basis of meaningful individual differences. If not, then the possibility has not been ruled out that a "good" separation into subgroups would yield individual differences in theoretically important personality variables. Such a conclusion would be in keeping with the suggestion that the Kruskal solutions of the Tucker subgroups are uninterpretable because the data of the subgroup members is essentially meaningless. If however, the Tucker technique is operating as desired, then the lack of individual differences in personality variables must be traced to inappropriate selection or unreliable measurement of the personality variables. The lack of interpretability of the Kruskal solutions of the Tucker subgroups, then, must be traced not to meaninglessness of the similarity data, but to the lack of robustness of the Kruskal technique with respect to sampling error in small samples. Based upon results reported in section 4.8, it was decided to analyse the Tucker subgroup data by Carroll analysis. Such results are reported in section 4.8, and shed light on the hypothesis under discussion.

4.7 Carroll Scaling Results-Cognitive Structures

Carroll scaling was performed on the eight sets of data. In order to check for local minima, the analysis was performed twice, using first a random number starting configuration, and second the group average Kruskal results as starting configuration. Table XIV presents the goodness - of-fit relationships among the two Carroll solutions, the Kruskal solutions, and the data. From Table XIV, it can be seen that there is little to choose between the "random number" start and the "Kruskal" start Carroll scaling

TABLE XIV

RELATIONSHIPS AMONG CARROLL SOLUTIONS, KRUSKAL SOLUTIONS, AND DATA FOR FULL GROUPS

Data sets	1	2	3	4	5	6	7	8
CAU9	0.02	1.00	0.61	0.79	0.62	0.78	0.60	0.60
CAU12	0.14	0.99	0.66	0.75	0.63	0.77	0.58	0.58
CAS9	0.02	1.00	0.51	0.86	0.52	0.85	0.60	0.60
CAS12	0.14	0.99	0.67	0.74	0.65	0.76	0.58	0.58
SJ9	0.15	0.99	0.31	0.95	0.33	0.95	0.64	0.64
SJ12	0.14	0.99	0.48	0.88	0.48	0.88	0.59	0.60
SD9	0.00	1.00	0.59	0.81	0.59	0.81	0.50	0.50
SD12	0.03	1.00	0.34	0.94	0.34	0.94	0.51	0.51

1. Fit of "random start" and "Kruskal start" Carroll results to each other - SS
2. Fit of "random start" and "Kruskal start" Carroll results to each other - r
3. Fit of "random start" Carroll results to Kruskal group average results - SS
4. Fit of "random start" Carroll results to Kruskal group average results - r
5. Fit of "Kruskal start" Carroll results to Kruskal group average results - SS
6. Fit of "Kruskal start" Carroll results to Kruskal group average results
7. Average correlation of "random start" results to data
8. Average correlation of "Kruskal start" results to data

results. Their fits to each other are almost perfect, and their fits to the Kruskal group average results are virtually identical. Perfect fit to the Kruskal group average results was not expected. In the Kruskal technique, all subject ratings are given equal weight by the averaging process. In the Carroll technique, on the other hand, subjects closer to the group average are more heavily weighted. Since there was no criterion by which to choose between the two Carroll analyses, the "random number" start results were arbitrarily chosen for subgroup formation and further reporting.

Unlike the Tucker scaling technique, the number of dimensions on which subjects are separated and the number of dimensions on which concepts are rated are the same. In the Tucker analysis, it was possible to use four dimensions of the principal components analysis in order to form subgroups and still report three dimensional cognitive structures for those subgroups. In the Carroll technique, subject space and stimulus space must be of the same dimensionality. The Carroll analysis was carried out in four dimensions as well as in three. Over all eight data sets, the average correlation between the data and the Carroll solutions was 0.62 for four dimensions compared with 0.58 for three dimensions. The slight increase in this value, which is analogous to a goodness-of-fit measure, was not considered worth the sacrifice of interpretability which the addition of a fourth dimension would entail. The three dimensional solutions are reported, and were used to form subgroups.

The Carroll results can produce subgroup cognitive structures directly by calculation of weighted composites of the loadings of concepts on each dimension. Saliences of dimensions for subjects are the weights used in this process. This was the procedure by which the elegant solutions of the "rating of nations" or the "colourblind" examples were obtained. In the present situation, the average correlation of the results with the data is relatively low. Rather than opt for the weighted composite procedure, it was decided to use the weights of subjects on dimensions to produce subgroups in a manner analogous to that used with the Tucker results. That is, subjects were grouped according to their saliences on dimensions, but their raw data were then used for averaging to produce a subgroup similarity matrix for Kruskal scaling. As noted above (P.48), this procedure is one less best fit step removed from the raw data than the procedure recommended by Carroll.

The criteria introduced for subgroup membership were, of necessity, different from those employed with the Tucker results. In the Tucker scaling technique, the dimensions produced in the principal components analysis appeared to bear no direct relationship to the dimensions along which subjects rated concepts. Loadings on dimensions indicate only similarities and differences in the raw similarity judgments. Thus, a subject who loaded highly on, for example, both dimensions two and three could justifiably be considered not to be in the same subgroup as those who loaded highly only on dimension two or only on dimension three. On the other hand, the Carroll analysis produces subject loadings which indicate directly the importance of each of the underlying dimensions of judgment to the subject. If we are attempting to isolate those subjects for whom, for example, dimension two was important in their ratings of concepts, then a high loading on another dimension is not sufficient grounds for excluding a subject from the "dimension two" group. The criteria for subgroup formation based upon the Carroll analyses were: for each dimension, take the ten highest (grade nine, N=78) or eight highest (grade twelve, N=54) loadings on each of the three dimensions as indicating group membership. Such a procedure appears reasonable because it groups 41 percent of subjects in three groups compared to 61 percent in four groups for the Tucker grouping. Since, therefore, the average subgroup is approximately the same size in both the Tucker and Carroll groupings, homogeneity and sampling error should be comparable. Three groups were formed from each data set, giving 24 groups in total. Unlike the Tucker groups, these groups were not mutually exclusive. Subject loadings on dimensions for the Carroll analyses are presented in Tables XL to XLVII in Appendix B. Group membership is presented in Table XV.

Substantial commonality of group membership was

TABLE XV

CARROLL SUBGROUP MEMBERSHIP

Data set		Subject ID's
CAU9	Group 1	3,10,25,35,38,41,42,61,62,64
	Group 2	2, 9,13,17,27,40,44,54,57,60
	Group 3	2, 6, 8, 9,33,37,43,49,53,63
CAU12	Group 1	11,17,24,27,34,39,49,54
	Group 2	12,17,26,31,40,44,47,48
	Group 3	8,13,14,19,24,29,45,50
CAS9	Group 1	2, 6, 8, 9,12,37,43,49,53,63
	Group 2	2,10,25,35,38,41,42,61,62,64
	Group 3	2, 9,13,17,27,40,44,54,57,60
CAS12	Group 1	11,17,24,27,34,39,49,54
	Group 2	11,12,17,18,26,31,47,48
	Group 3	8,13,14,19,24,29,45,50
SJ9	Group 1	8, 9,15,31,33,43,49,57,63,78
	Group 2	2, 3,12,13,25,32,40,44,61,62
	Group 3	21,27,38,39,49,59,65,66,71,76
SJ12	Group 1	4,16,17,21,31,34,49,54
	Group 2	5,19,22,25,29,36,44,45
	Group 3	1, 2, 8,12,15,19,32,44
SD9	Group 1	8,24,26,41,45,55,59,65,66,76
	Group 2	3,12,15,18,27,38,49,67,72,75
	Group 3	7,14,15,17,29,51,61,64,71,74
SD12	Group 1	11,21,22,38,40,41,42,54
	Group 2	6,10,17,28,45,46,47,50
	GROUP 3	1,15,20,21,26,31,34,52,

found. With the exception of two pairs of subjects, grouping in the constrained association test groups for the scaled and unscaled data are identical for both grades. For grade nine, constrained association unscaled group one and similarity judgment group three have six members in common. Group two of the similarity judgment grade nine has four members in common with each of the first two groups of the constrained association data. Also for grade nine, semantic differential group one has four members in common with similarity judgment group three. In the grade twelve memberships, constrained association unscaled group one has four members in common with similarity judgment group one, and constrained association-scaled group three has three members in common with similarity judgment group two. These commonalities are in marked contrast to the groupings based upon the Tucker scaling results. While the grouping criteria in the Tucker technique prevented the subject from being placed in more than one group within a data set, there is no such restriction applied to the subjects with whom he is grouped across data sets. The commonalities between the scaled and unscaled versions of the constrained association data are predictable on the basis of the strong fit between the Kruskal group average results for these four data sets. These commonalities, and even more so the commonalities across different similarity rating instruments are strong evidence both for the construct validity of the cognitive structures uncovered, and for the power of the Carroll scaling technique. The fact that, responding to different similarity instruments, subjects were grouped together in the same groups on the basis of response similarity indicates a high consistency of response across instruments. This is deemed to be evidence for the construct validity of cognitive structure.

The subgroup average matrices were analysed by the Kruskal technique in order to seek evidence for differences among subgroups in cognitive structure. Stress values for five, four, and three dimensions are presented in Table XVI. As with the Tucker results, the stress values are quite high. Again, this may be traced to the small group size. There are no trends in stress evident either within Table XVI, or from comparing this table with the corresponding table (Table XI) for the Tucker groups. Kruskal solutions for each of the 24 subgroups were rotated within each data set by the nonmetric orthogonal Procrustes rotation. Measures of fit are summarized in Table XVII. A comparison of this table with the corresponding table for the Tucker group rotations (Table XII) shows measures of fit of the same order of magnitude for both subgroup results. The Carroll subgroup results fit each other and the full group results slightly better than the Tucker subgroup results. The average correlations with the whole group average and among the subgroups are, for the Tucker results, 0.20 and 0.44 respectively, while the corresponding values for the Carroll results are 0.24 and 0.48. The Kruskal scaling

TABLE XVI

STRESS 1 VALUES FOR KRUSKAL SOLUTIONS OF CARROLL SUBGROUP AVERAGE MATRICES

Data sets		Dimensions 5	4	3
CAU9	Group 1	11.8	15.4	21.4
	Group 2	13.9	17.6	23.4
	Group 3	12.0	16.0	21.7
CAU12	Group 1	13.9	16.2	21.7
	Group 2	11.9	15.2	20.9
	Group 3	11.9	15.5	21.3
CAS9	Group 1	13.1	17.0	22.6
	Group 2	10.8	14.8	20.8
	Group 3	13.6	16.9	21.8
CAS12	Group 1	12.7	16.7	22.5
	Group 2	10.9	13.9	19.7
	Group 3	11.5	15.2	20.8
SJ9	Group 1	13.6	17.3	22.4
	Group 2	13.1	16.0	21.3
	Group 3	13.0	15.4	20.7
SJ12	Group 1	13.1	16.9	22.7
	Group 2	12.2	14.6	20.4
	Group 3	11.0	14.1	18.7
SD9	Group 1	14.1	17.0	21.7
	Group 2	12.3	16.4	21.9
	Group 3	13.7	16.4	21.9
SD12	Group 1	12.7	17.1	21.6
	Group 2	13.9	16.8	22.6
	Group 3	12.7	16.3	21.3

TABLE XVII

GOODNESS-OF-FIT AMONG CARROLL SUBGROUP KRUSKAL SOLUTIONS AND WITH RESPECTIVE FULL GROUP KRUSKAL SOLUTIONS

		Grade 9				Grade 12			
		0	1	2	3	0	1	2	3
CAU Grp	0		23	17	18		25	33	25
	1	97		43	50	97		47	41
	2	98	90		49	95	88		36
	3	98	87	87		97	91	93	
CAS Grp	0		27	25	15		19	30	20
	1	96		52	56	98		50	61
	2	97	86		43	95	87		50
	3	99	83	90		98	79	86	
SJ Grp	0		26	20	16		25	12	18
	1	96		47	35	97		47	35
	2	98	88		63	99	88		77
	3	99	94	78		98	94	64	
SD Grp	0		29	24	22		25	38	36
	1	96		51	41	97		31	46
	2	97	86		49	92	95		45
	3	98	91	87		93	89	90	

Below diagonal - SS; above diagonal - r
Decimals omitted

solutions for the 24 subgroups are reported in Table XLVIII in Appendix B. Further discussion of the interpretation of these scaling results will be left until section 4.8, which will present the differences in personality variables among the subgroups.

4.8 Carroll Scaling Results-Personality Variables

As with the examination of the personality variables of the Tucker subgroups, this part of the analysis was carried out by one way analysis of variance, using a criterion of 0.01 for statistical significance. Because of the somewhat dubious appropriateness of using one way analysis of variance, there is a danger of Type 1 error in searching for differences in personality variables among the subgroups. In order to minimize this danger, the stringent criterion of 0.01 has been used. A summary of the significance levels of differences in the variables is presented in Table XVIII. The results are similar to those for the Tucker groups. Significant differences in two cases for one of the internally generated variables were found, and a sex difference emerged in another two cases. Rotations of these subgroup solutions to a best fit with the appropriate Kruskal group average solution revealed a general lack of interpretability of the solutions. The situation is similar to that involving the Tucker solutions, except that in the Carroll case, a measure of correlation of the solution with the data is available. As reported above,

TABLE XVIII

ANALYSIS OF VARIANCE-PERSONALITY VARIABLES AMONG CARROLL SUBGROUPS

Grade 9	CAU		CAS		SJ		SD	
	F	p	F	p	F	p	F	p
Age	1.3	.30	1.3	.30	0.5	.64	1.2	.31
Sex	6.7	.004	6.8	.004	0.4	.69	1.2	.32
I.Q.	0.6	.56	0.7	.50	0.0	.99	1.1	.34
Achievement	0.2	.79	0.0	.96	3.6	.04	0.3	.75
Hidden Figures	0.2	.86	0.2	.84	0.3	.74	0.1	.92
Developmental Level	0.6	.56	0.3	.75	0.2	.83	2.1	.14
Cognitive Complexity	1.4	.27	1.3	.30	1.0	.38	2.2	.13
Consistency-SJ	1.0	.40	0.5	.64	1.1	.35	0.2	.85
Consistency-SD	0.6	.57	1.3	.30	1.1	.34	0.3	.76
Consistency-CA	0.2	.80	0.1	.93	0.1	.90	0.9	.43
Total responses-CA	0.4	.71	0.7	.50	0.7	.51	0.5	.61
Internal responses-CA	1.3	.28	1.9	.18	0.5	.64	1.3	.30
Fraction internal	3.2	.06	5.0	.014	0.7	.51	1.3	.30
Avg.relatedness index	0.8	.47	1.2	.31	0.2	.79	1.3	.29
Personal Consistency	1.4	.26	2.2	.13	1.3	.30	2.0	.16

Grade 12	CAU		CAS		SJ		SD	
Age	1.4	.27	1.9	.18	1.1	.36	1.7	.21
Sex	1.3	.30	1.3	.30	1.4	.27	0.6	.55
Achievement	0.2	.79	0.5	.62	0.9	.41	0.7	.53
Hidden Figures	0.1	.90	0.0	.99	1.2	.31	2.5	.11
Developmental Level	3.0	.07	3.0	.07	0.8	.45	2.2	.13
Cognitive Complexity	2.3	.12	2.0	.17	1.9	.18	0.0	.96
Consistency-SJ	0.0	.98	0.6	.55	3.1	.07	0.8	.47
Consistency-SD	1.0	.40	0.9	.44	0.2	.85	1.3	.29
Consistency-CA	0.5	.60	0.5	.63	1.4	.28	0.6	.58
Total responses-CA	0.4	.66	1.0	.38	1.2	.31	0.8	.48
Internal responses-CA	0.8	.47	1.6	.22	0.1	.93	1.7	.21
Fraction internal-CA	0.7	.53	1.0	.38	0.4	.65	2.4	.12
Avg.relatedness index	1.3	.29	2.3	.12	0.1	.91	3.7	.04
Personal Consistency	4.7	.02	3.8	.04	1.1	.35	2.4	.12

Notes:

1. Three decimals reported for significant or near significant differences only.
2. df - groups = 2 for all data sets
3. df - error = 27 for grade 9 and 21 for grade 12

the average correlation of the Carroll solutions for all subjects over all data sets was 0.58. However, for those subjects who met the criteria for subgroup membership, this average correlation was 0.68. This substantial difference prompted the investigator to perform Carroll scaling on the subgroups in order to achieve solutions which would not require rotation to meaningfulness. Similar analysis, as mentioned above, was performed on the Tucker subgroups. The Carroll solutions of the Carroll subgroups are reported in Table XLIX, and those for the Tucker subgroups in Table L, both in Appendix B. The interpretations of the dimensions uncovered are summarized in Table XIX for the Carroll subgroups, and in Table XX for the Tucker subgroups. As can be seen from Table XIX, 80 percent of the dimensions for the Carroll subgroups can be assigned meaning on the basis of the criteria used in the analysis of the large group solutions. As can be seen from Table XX, about 70 percent of the dimensions are interpretable for the Tucker subgroups. Substantial individual differences among the solutions can be seen. The fits of these Carroll solutions to the corresponding subgroup average Kruskal solutions are also included in Tables XIX and XX. Since it was not possible to identify the members of the subgroups, little will be achieved by a detailed discussion in terms of the concept meanings of the manner in which the cognitive structures differed. However, the meaningfulness of the solutions suggests that, in fact, the Tucker scaling technique is not

TABLE XIX

INTERPRETATIONS OF DIMENSIONS IN CARROLL SOLUTIONS OF TUCKER SUBGROUPS AND FIT WITH KRUSKAL SOLUTIONS

Data set		Dim.1	Dim.2	Dim.3	SS	r
CAU9 Grp	1	1	2	3	0.96	0.28
	2	2	0	3	0.99	0.08
	3	4	2	3	0.98	0.21
	4	1	4	0	0.99	0.14
CAU12 Grp	1	2	4	0	0.92	0.40
	2	1	0	0	0.95	0.32
	3	1	0	0	0.99	0.13
	4	1	0	0	0.98	0.21
CAS9 Grp	1	1	3	2	0.99	0.10
	2	1	3	0	0.99	0.17
	3	1	3	0	0.98	0.19
	4	4	1	3	0.99	0.14
CAS12 Grp	1	0	0	2	0.98	0.19
	2	1	3	0	0.97	0.23
	3	2	0	3	0.97	0.23
	4	4	3	0	0.99	0.12
SJ9 Grp	1	4	1	3	0.99	0.16
	2	2	3	1	0.99	0.10
	3	1	4	3	0.99	0.14
	4	4	1	2	0.96	0.27
SJ12 Grp	1	4	0	0	0.98	0.20
	2	1	3	4	0.98	0.18
	3	4	0	2	0.99	0.15
	4	1	2	4	0.98	0.18
SD9 Grp	1	1	0	3	0.99	0.14
	2	1	4	0	0.99	0.17
	3	2	4	0	0.99	0.11
	4	1	4	0	0.99	0.14
SD12 Grp	1	0	1	0	0.99	0.16
	2	1	3	3	0.97	0.25
	3	4	3	0	0.97	0.26
	4	1	0	0	0.99	0.08

0 - No clear interpretation
1 - Certainty
2 - Creativity
3 - Theoretical-practical
4 - Temporal

TABLE XX

INTERPRETATIONS OF DIMENSIONS IN CARROLL SOLUTIONS OF CARROLL SUBGROUPS AND FIT WITH KRUSKAL SOLUTIONS

Data set		Dim.1	Dim.2	Dim.3	SS	r
CAU9 Grp	1	1	0	2	0.98	0.18
	2	1	4	3	0.98	0.20
	3	1	4	3	0.96	0.27
CAU12 Grp	1	4	0	3	0.99	0.17
	2	0	3	0	0.97	0.26
	3	1	3	0	0.99	0.10
CAS9 Grp	1	1	4	2	0.95	0.30
	2	1	3	2	0.98	0.17
	3	1	4	3	0.98	0.19
CAS12 Grp	1	1	3	0	0.98	0.18
	2	1	2	4	0.99	0.13
	3	4	1	3	0.99	0.11
SJ9 Grp	1	4	1	0	0.99	0.10
	2	1	3	4	0.99	0.14
	3	4	3	1	0.99	0.15
SJ12 Grp	1	4	1	3	0.94	0.32
	2	1	3	3	0.99	0.13
	3	1	0	0	0.99	0.12
SD9 Grp	1	3	0	0	0.95	0.30
	2	2	0	1	0.98	0.21
	3	1	1	2	0.99	0.15
SD12 Grp	1	1	2	1	0.99	0.11
	2	1	3	4	0.99	0.13
	3	0	1	0	0.99	0.17

0 - No clear interpretation
1 - Certainty
2 - Creativity
3 - Theoretical-practical
4 - Temporal

operating solely on chance fluctuations, but on some real but unidentified individual differences.

It should be noted that the assignment of labels to dimensions is a very subjective process on the part of the investigator. The dimension labels used have enough conceptual overlap to render almost impossible the replication by another judge of the labels assigned. Because of this difficulty, it has been decided not to proceed with attempts to link differences in cognitive structure with differences in personality variables, for the few cases where such differences were found. Such linking would likely amount to overinterpretation of the data.

The goodness-of-fit measures among the Carroll solutions for full groups and Carroll subgroups are reported in Table XXI, and among the full groups and Tucker subgroups in Table XXII. The goodness-of-fit measures are substantially higher, both among the subgroups and with the full groups, than the corresponding measures for the Kruskal solutions (see Tables XII and XVII). The magnitudes of the values in Tables XXI and XXII indicate a reasonable balance between no individual differences (as would be indicated by SS values of 0.00) and individual differences so extreme (as would be evidenced by Tables XII and XVII, assuming that the Kruskal subgroup solutions had been clearly interpretable) that little commonality of perception among subgroups could be imputed. For the purposes of addressing the hypotheses of this study, even though the dimension interpretations

TABLE XXI

GOODNESS-OF-FIT MEASURES AMONG THE CARROLL SOLUTIONS OF FULL GROUPS AND CARROLL SUBGROUPS

Data Sets		Grade 9 Groups				Grade 12 Groups			
		0	1	2	3	0	1	2	3
CAU Grp	0		90	80	79		88	86	75
	1	45		69	66	48		78	70
	2	60	72		75	50	62		55
	3	62	75	66		66	72	84	
CAS Grp	0		90	89	80		86	80	75
	1	43		80	73	52		93	70
	2	45	61		69	60	36		67
	3	60	68	72		66	71	75	
SJ Grp	0		90	91	84		85	95	73
	1	44		78	76	53		83	64
	2	41	62		84	30	55		72
	3	55	65	55		68	77	70	
SD Grp	0		79	71	90		76	73	79
	1	61		52	64	65		50	64
	2	71	85		68	68	86		59
	3	43	77	73		62	76	81	

Below diagonal - SS; above diagonal - r
Decimals omitted

TABLE XXII

GOODNESS-OF-FIT MEASURES AMONG THE CARROLL SOLUTIONS OF FULL GROUPS AND TUCKER SUBGROUPS

Data sets		Grade 9 Groups					Grade 12 Groups				
		0	1	2	3	4	0	1	2	3	4
CAU Grp	0		76	73	94	79		76	85	84	91
	1	65		72	70	61	65		26	80	65
	2	69	70		71	70	53	78		73	76
	3	35	72	71		80	54	60	69		77
	4	61	79	71	60		41	76	65	64	
CAS Grp	0		92	83	85	91		74	75	88	74
	1	40		77	76	79	67		67	70	74
	2	55	64		83	78	66	74		73	62
	3	52	65	55		78	47	72	69		73
	4	41	61	63	63		67	68	78	68	
SJ Grp	0		81	92	94	95		77	81	90	72
	1	59		80	71	82	64		32	36	82
	2	38	60		83	89	58	95		72	76
	3	35	70	56		85	44	94	69		70
	4	32	57	46	53		69	95	65	72	
SD Grp	0		75	75	74	81		79	77	61	82
	1	67		53	64	54	62		56	50	62
	2	66	85		61	78	63	83		59	61
	3	67	76	80		52	80	86	81		61
	4	59	84	62	86		58	79	79	79	

Below diagonal - SS; above diagonal - r
Decimals omitted

themselves are no longer of interest without identifiable differences among subgroup members, the fact that such labelling is possible, and the fact that individual differences in configuration were found as evidence of individual differences in cognitive structure are relevant.

A major hypothesis of the study was that individual differences could be found in cognitive structures relating the 15 concepts under investigation. Such differences were found by both the Tucker and Carroll techniques of subgroup formation. The subgroups formed by the two techniques, however, bore no relationship to each other. The personality variables used for subject identification in the study were not useful as descriptors of subgroup members.

4.9 Summary

The hypotheses of this study sought evidence for convergent validity of cognitive structures through analysis of similarity data obtained through three different instruments from the same subjects, and indirect evidence for discriminant validity of cognitive structures through identification by independent means of subgroups which differed in cognitive structure. Convergent validity was to be enhanced by applying two scaling techniques to the data. These techniques differed in assumptions and computational methods. Discriminant validity was to have been enhanced by explanation of differences in cognitive structure by differences in independent personality variables.

Based upon the group average data (see H0(1), section 1.7), convergent validity between the constrained association data and the similarity judgment data was judged satisfactory. The fit of the semantic differential results to the other two was considerably lower. Using the grade of subjects as an independent variable, it was not possible to produce the low goodness-of-fit measures between grades which would have been positive evidence of good discriminant validity. Since it is not clear on theoretical grounds that grade should be a discriminating variable, it is difficult to assess the importance of this lack of discriminant validity.

For H0(2) and H1(2) (section 1.7), the measures of two of the personality variables, the developmental level test and the Hidden Figures Test were judged to be sufficiently reliable for their intended purposes of subject identification. The cognitive complexity test did not prove to have sufficient test-retest reliability. None of the independent variables chosen for study had any value in identifying subgroup members. Thus, it was not possible to link differences in cognitive structure with differences in personality variables.

The Tucker and Carroll techniques both appeared to operate successfully in separating the subjects into groups with differing cognitive structures. These separations, however, bore no relationship to each other. Since no consistencies of group membership were found between the

Tucker subgroups and the Carroll subgroups, the approach to convergent validity which used similar results based upon two different analytic techniques proved fruitless. There was evidence that the error level of subgroup data was too high for the Kruskal technique to uncover meaningful cognitive structures. If this is the case, then Wagenaar and Padmos (1971) may have underestimated the effect of error on stress for the Kruskal technique. According to their criteria, the stress of the solutions of the subgroups was not high enough to indicate that the proportion error in the data would render interpretation meaningless.

Using the Carroll technique on the subgroup data, meaningful and different cognitive structures were recovered for the subgroups. In finding meaningful individual differences in cognitive structure, the study has achieved some degree of success. Dimensions labelled "certainty", "creativity", "temporal", and "theoretical-practical" were identified in various combinations as being reasonable interpretations of subject scaling result dimensions. In linking these differences to independent variables, the study has not been successful. The next chapter will discuss the educational implications of this line of research, will suggest possible improvements to this study, and will make recommendations for further research.

CHAPTER 5

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter will proceed in three main sections. The next section will summarize the study. Section 5.3 will discuss the educational implications of the study. Section 5.4 will suggest how this study could have been improved upon while maintaining essentially the same format, and will discuss further suggested research which may add to the body of knowledge concerning cognitive structure.

5.2 Summary of Study

This study examined the construct validity of cognitive structures, defined as sets of relationships among concepts. Construct validity was assessed primarily by convergent validity (Campbell and Fiske, 1959) and indirectly by discriminant validity. The investigation proceeded by multidimensional scaling analysis of concept similarity data obtained from 78 grade nine science and 54 grade 12 biology students. Using a set of 15 syntactical concepts from the domain of the scientific method subjects responded to three concept rating tests: a constrained association test (Garskof and Houston, 1963), a similarity judgment test (Torgerson, 1958), and a semantic differential test (Osgood, 1957). Personality data were also gathered from the subjects in the form of tests of developmental level (Inhelder and Piaget, 1958; Hobbs, 1975), field independence-dependence (French et al, 1965), and cognitive complexity (Seaman and Koenig, 1974).

Validity was investigated through the scaling technique of Kruskal (1964a; 1964b) applied to group average data, and through subgroup formation based upon individual differences in similarity judgments as revealed by Tucker and Messick (1963) points-of-view analysis and Carroll and Chang (1970) individual differences analysis. The measure of convergence of scaling solutions was a non-metric version of the orthogonal Procrustes rotation (Schonemann and Carroll, 1970; Lingoes and Schonemann, 1974).

It was hypothesized that individual differences in cognitive structures would be linked to individual differences in personality variables. In addition to the three tests of personality variables administered, other variables investigated included age, sex, grade, achievement, I.Q., and several variables relating to personal consistency of response on the similarity measures and fluency of response on the word association test.

All configurations reported are in three dimensions. The goodness-of-fit, taken as evidence of convergent validity, was quite high between the group average data of both grades for the word association test and the similarity judgment test (average r=0.90). Goodness-of-fit was considerably lower (average r=0.67) for the semantic differential data. Both the Tucker and Messick technique and the Carroll and Chang technique produced subgroups with interpretable configurations, indicating evidence for the construct validity of cogntive structure. Measures of goodness-of-fit between these subgroup solutions were neither high nor low (average r=0.67), indicating some evidence for individual differences in cognitive structures. Subgroups formed by the two scaling techniques bore no relationship to each other, but subgroups formed on different similarity measures using the Carroll and Chang method bore strong resemblances to each other. Interpretability of subgroup configurations produced by the Kruskal technique was low, possibly due to high error in the data. The Carroll and Chang technique, however, produced interpretable results, and thus was judged relatively robust with respect to error.

The study provided some construct validity for the interpretation of configurations as cognitive structures based upon data obtained by word association and similarity judgment. Individual differences in cognitive structure were found in the configurations of the subgroups formed.

None of the personality variables examined were fruitful in identifying members of subgroups formed. With the exception of the cognitive complexity test, reliabilities of the personality variables were satisfactory, with estimates by various methods ranging from 0.50 to 0.76. There was some consistency of subgroup membership within the subgroups formed by the Carroll and Chang analysis, but not among those formed by the Tucker and Messick analysis on the different data sets.

5.3 Educational Implications

It has been suggested (Shavelson, 1974) that, over the course of instruction, the cognitive structures of students should be altered in the direction of that of the instructor. While a similarity judgment test cannot be imagined as a useful posttest grading device, it has potential application as a pretesting device. The particular set of concepts chosen for this study have limited educational import. It is of interest, however, that scientific method is perceived by subjects as varying along at least three, and possibly four dimensions. Tentative labels for some of the subject perception dimensions were certainty, creativity, temporal, and theoretical-practical. It is possible that those subjects who perceived a creativity dimension to the scientific method may be more aware of science as the product of human imagination than those who did not. The "theoretical-practical" dimension may be related to subjects' perception of the difference between science and technology, a difference which is not always clear in the minds of the public. Similarly, the perception of a "certainty" dimension, while almost universal among the subgroups, could be related to the view of science as an explainer rather than a producer of goods. This distinction is closely related to the science-technology distinction.

However, for a set of more substantive science concepts, it may be possible to ascertain along which dimensions of cognitive structure a subject was similar to the instructor (or to the "target"), and along which he was different. Such a finding could have implications for the design of individualized instruction. Hunt (1971) has suggested that it may be possible to design instruction to fit a student's cognitive style, or preferred way of learning. It may also be possible to match student and teachers who have the same perceptions of a concept domain, or who have compatible styles of thought. Hunt also suggests that perhaps we should be "mismatching" students with teachers in order to introduce students to different thinking patterns and increase their cognitive flexibility. In either case, cognitive structure may be an educationally important variable for the design of individualized instruction.

By extension of the technique, it may be possible to develop posttesting devices. Consider a situation where the instructors have identified the dimensions along which they wish subjects to be able to distinguish among a set of concepts. A possible posttest could be devised which involved rank ordering concepts along several continua. It is difficult to see any immediate advantages of such a testing method over more traditional testing methods, but the notion should not be ignored because its direct application cannot be foreseen at present. Attempts have begun (Shavelson and Geeslin, 1975) to apply the techniques of scaling theory and graphing theory to the recovery of structural information from textual material. Undoubtedly, the same is possible for interactional analysis data. The technique has the potential to become an important analytic tool for the analysis of nuances of meaning conveyed by teachers and students in classroom discourse. As noted by Hartnett and Rumery (1973), the mathematical analysis of classroom interaction data is in its infancy.

Perhaps the most fruitful applications of the technique will be noticed after the high error levels in the data have been reduced. It may be possible to train subjects in a relatively short period of time to be more consistent in their reponses. Since this study has touched upon only three of the many possible methods of gathering similarity data, perhaps another method of data collection will prove more error-free.

Assuming that the error in the data can be reduced substantially, further research in the area will reveal further possibilities for the application of cognitive structure. In theory, all the educational advantages of the precise measurement of individual differences apply to the recovery of structural information from student data. There is considerable error in the data obtained from subjects in this study. It is not clear whether this error is due to limitations of the techniques or to lack of stability in perception or lack of accurate introspective ability on the part of the subjects. The conversion of word association lists to relatedness indices loses a great deal of information about subjects' perceptions. The failure of many subjects to confine themselves to the constraints of the word association test was surely a confounding factor in the analysis. Further modification of the directions given to the subjects may lessen these problems. No attempt was made in the study to use redundant information supplied by the similarity judgment test responses to estimate subject response stability. How this should be done is not clear, but redundancy of information should not be ignored in attempts to improve the accuracy of the similarity matrices produced from subject responses. The semantic differential test did not correlate as well as might be hoped with the other two similarity rating tests. Analysis of the data of this test by more traditional semantic differential techniques might shed light on the usefulness of the particular bipolar scales chosen for the concepts and subject ages studied. This was a technique of instrument refinement not used in the study.

There is considerable variation in the literature in the nature of the directions given for the constrained association test. A balance must be struck between focusing subjects on the concept domain of interest and stifling their fluency of response. For example, it is possible that the legal connotations of "law" and "evidence" may have interfered with subject responses to these concepts in the scientific context of this investigation. Instructions which ask subjects to list words they would use in explaining or defining the concepts, despite the predicted effect on fluency of response, may prove to be more useful for testing in an educational context.

The personality variables measured in this study did not prove fruitful in the analysis of individual differences. The developmental level test concentrated on the ability to combine and control variables at the expense of other aspects of formal thought, such as proportional ability. Because of this limitation, and because of the conceptual difficulty involved in estimating the reliability of the measure, the measure in retrospect seems inadequate for the task. The cognitive complexity test was even less reliable than previous instruments reported in the literature which have attempted to measure this variable. It is not clear how reliability of the instrument could be improved within the time constraints of this study. Assuming the construct is educationally useful, which is not established, then more testing time should have been devoted to its measurement. Since it would have been next to impossible to ask for a fourth class period, perhaps a better approach would have been to not administer the semantic differential instrument and concentrate on a longer and better estimate of cognitive complexity.

The scaling techniques used did not operate equally efficiently on the data provided. The Tucker technique must be judged inferior to the Carroll technique because of the lack of consistency in group membership across data sets. The Kruskal technique failed to provide meaningful information when operating on the subgroup data, presumably because of the high noise ratio in the data. Because of this, its accuracy for the full group data must also be questioned. Perhaps use of the Carroll technique in a manner which utilized the saliences of the dimensions would have been more informative. The reversion to the Kruskal analytic technique for the subgroup configurations was, in retrospect, unwise.

Because of the error in the data, no attempt was made to distinguish subjects who were using a two dimensional perspective from those who were using a three or four dimensional one. The question of "true" dimensionality of the solutions has to some extent, and of necessity, been avoided. Until more is known about the behaviour of Kruskal and Carroll scaling techniques under conditions of varying error and dimensionality, the problem of dimensionality of subjects' cognitive structures will remain an open question.

One suggestion which was tried and proved fruitless involves formation of subgroups based directly on personality variables. Subgroups were formed consisting of those one standard deviation above and one standard deviation below the mean on each variable. Kruskal analysis of subgroup average data produced dimensions uninterpretable by the investigator. Carroll analysis of this data was not attempted.

Returning to the question of the educational implications of the field of cognitive structure, it is not clear, despite the many untried and suggested possibilities, that the construct has any potential importance beyond theoretical interest. It is difficult to wax enthusiastic about the practical consequences for educational practice. This comment should not be construed as a suggestion that the field be abandoned, but only that the conceptual issues and instructional consequences be addressed at greater depth than has been done in the present study.

5.4 Recommendations for Further Research

This study has been exploratory in nature and its termination occurred at a somewhat arbitrary point. Although the questions posed have been addressed, the many fruitful avenues for data manipulation have not been explored. The study has shown that the recovery of individual differences in cognitive structure among subjects as young as the ninth grade is possible with relatively simple (for the subject) tests. To begin, techniques are needed for estimating the amount of error in the data. The Monte Carlo studies of Wagenaar and Padmos (1971) and Isaac and Poor (1974) have begun this work. The following studies are suggested:

1. Extension of the Monte Carlo studies to investigate situations where the true dimensionality is not exactly two or three dimensions, but perhaps an average of a true two dimensional and a true three dimensional pattern.

2. Assessment of the various methods of introducing random error into Monte Carlo studies in order to investigate which is most similar to the type of error produced by human subjects.

3. Monte Carlo studies comparing the accuracy of the Kruskal technique operating on an averaged solution with the Carroll technique operating over a set of individual matrices.

Further analysis may reveal whether or not those subjects who failed to load highly on the dimensions of the Carroll analysis were operating from unique perspectives or from confusion and error. It is suggested that:

4. Subjects who failed to analyse into subgroups on the Carroll analysis be regrouped and analysed again.

The method used for subgroup formation may not be the most appropriate. It is suggested that:

5. Alternative methods of subgroup formation, perhaps partly subjective, be explored in order to produce subgroups with identifiable differences in both cognitive structure and personality variables.

6. Techniques of multiple regression and discriminant analysis be attempted in order to identify linear combinations of personality variables which will characterize subgroup members.

Further use of the semantic differential technique in the manner of this investigation requires exploration of the relationship between this use of the technique and more traditional uses. The probability exists that the scales provided for subjects to rate the concepts did not exhaust the dimensions of semantic space used by the subjects in their views of the concepts. Further use of the semantic differential in studies of this nature is of theoretical interest only, as the construct validity of cognitive structure has been established by the convergence of the constrained association and similarity judgment tests. For exploration of the semantic differential, it is suggested that:

7. The data from the present study be factor analysed by methods common to semantic diferential research methodology to assess the adequacy of the instrument from the point of view of the semantic differential tradition.

8. That the number of bipolar scales be increased in an attempt to produce better "coverage" of the relevant dimensions of semantic space.

While it seems quite reasonable to extend the use of the constrained association test to twenty or more concepts, a complete similarity judgment test for such a large number of pairs of concepts would be a prohibitive task for a high school age volunteer subject. Research is needed on methods of deletion of pairs of concepts to shorten the test with minimal loss of information. It remains to be established whether or not a method of discarding data based upon the relative sizes of the dissimilarities is more efficient in terms of information retention than a random discarding scheme. Such a non-random method would be based upon the fact that more information is needed about the relative sizes of similarities of points closer together than of points farther apart. It is suggested that:

9. Studies such as those undertaken by Spence and Domoney (1974), which investigate the effect of incomplete similarity matrices on Kruskal solutions be expanded. There is a need for the investigation of the relative effects of random vs. systematic discarding of data.

10. Studies such as those outlined by Torgerson (1958) involving the use of subsamples of the similarity matrix to estimate consistency of response be carried out.

It seems quite clear that there are perspectives from which to view the concepts under study which cannot easily be explained by an outside adult observer. Given that it can be established that these perspectives are not merely random error, methods are needed for revealing the nature of the individual views of the concepts. Mass sampling large scale studies will probably not be effective for such a purpose. It is more likely that a combination of written essay (perhaps paragraph completion) tests and personal interviews will shed light on this area. Perhaps the training of subjects in introspective techniques would be useful here. The following exploratory studies are recommended:

11. Content analysis (Shavelson and Geeslin, 1975) of subject produced paragraphs explaining the concepts of interest.

12. Triad studies such as those used in development of the instruments of this study. Subjects would be asked to indicate as many ways as possible that one concept in a triad differed from the other two.

13. Exploration of the possibilities of training subjects in techniques designed to reduce error in their similarity judgments.

The adequacy of geometric models of cognitive structure is not established. Some work has been done on non-geometric models such as hierarchical clustering (S.C. Johnson, 1967), tree construction (Shavelson, 1974), and lexical graphing (Rapoport et al. 1966). While these techniques seem to require extensive subject training, and perhaps must be limited to older subjects, their use may be necessary in cases where there is a tendency on the part of multidimensional scaling techniques to produce a degenerate solution. It is suggested that:

14. Techniques be explored for making the method of tree construction clear to high school age subjects.

15. Following the above, correlation between tree construction and similarity rating techniques used in this study should be established. The investigation may be extended to situations where geometrical models may be

expected to degenerate.

Wexler and Romney (1972) have devised a methodology for identifying individual differences. On the basis of subject responses, they calculated similarities between subjects. Kruskal scaling of the subject similarities then produced a map of subjects in geometrical space. Because of the general lack of success of the investigation in appropriate identification of individual differences among subjects, the approach of Wexler and Romney may prove valuable in more specific identification of subject characteristics with individual differences in cognitive structures. Perhaps goodness-of-fit measures on scaling solutions of individuals differentiated on several different criteria, such as responses, biographical data, etc, may provide insight into the type of variables best associated with individual differences in cognitive structure. However, such techniques, exotic and interesting as they are, may prove no more effective than conventional methods. It is recommended that:

16. A subjects by subjects correlation matrix be formed from the vectors of similarity ratings produced by the subjects. This correlation matrix should then be scaled by the Kruskal technique, and loadings on dimensions correlated with personality variables. Perhaps a discriminant function could be applied to the data to identify linear combinations of personality variables useful in differentiating among those with differing perceptions of the concepts. This suggestion

amounts to a nonmetric version of the Tucker method.

The relative robustness of the Carroll technique with the type of data used in the present study may make it the preferred analytic technique for the further investigation of cognitive structure. This use of the Carroll technique has serious consequences concerning the cost of such studies, although no suggestions for further research can be put forward at this time. If multiple regression techniques are to be used for the identification of individual differences, then sample sizes considerably larger than those in the present study will be necessary. The computer costs of the Carroll analysis vary directly with sample size (and number of iterations). A run of the original INDSCAL program (Chang and Carroll, 1970) on 78 subjects required, on the University of Alberta's Amdahl 460/67 computer, about seven minutes of CPU time. Using the improved version, which became available near the end of the investigation, SINDSCAL (Pruzansky, 1975), this cost was cut in half.

Large scale data manipulation studies may not be the most efficient method of answering the questions which can be raised about cognitive structures. More varied experimental techniques are needed.

In conclusion, there is the possibility that the mathematical techniques of the scaling analyses have become overly sophisticated in relation to the type of input which can presently be provided. It is expected that future progress in the elucidation of cognitive structures will come only after considerable work has been done on reducing error in the data and on clarifying and measuring relevant personality variables.

BIBLIOGRAPHY

Aikenhead, Glen S. *Learning about the scientific enterprise in Saskatchewan high school chemistry classes: an evaluation.* Information and Research Report, Department of Curriculum Studies, College of Education, University of Saskatchewan, Saskatoon, 1972.

Ausubel, David P. Cognitive structure and the facilitation of meaningful verbal learning. in *Readings in the Psychology of Cognition.* ed. by R.C. Anderson and D.P.Ausubel. New York: Holt, Rinehart, and Winston. 1965

Bart, William M. The factor structure of formal operations. *British Journal of Educational Psychology,* 1971, *41,* 70-77.

Bieri, James *et al.* *Clinical and Social Judgment: the Discrimination of Behavioural Information.* New York: John Wiley and Sons, 1966. Pp 182-206.

Black, Max. Models and Archetypes. in *Philosophy of Educational Research* ed. by H.S.Broudy, R.H.Ennis, and L.I.Krimerman. New York: Wiley. 1973.

Boersma, Frederick J. Test-retest reliability of the CF-1 hidden figures test. *Educational and Psychological Measurement,* 1968, *28,* 555-559.

Braithwaite, Richard B. The structure of a scientific system in *Philosophy of Educational Research* ed. by H.S.Broudy, R.H.Ennis, and L.I.Krimerman. New York: Wiley, 1973.

Bruner, Jerome S. *The Process of Education.* New York, Random House, 1960.

Campbell, Donald T. and Fiske, Donald W. Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological Bulletin,* 1959, *56,* 81-105.

Carroll, John B. Words, meanings, and concepts. *Harvard Educational Review* , 1964, *34,* 178-202.

Carroll, J.Douglas. Individual differences and multidimensional scaling. In *Multidimensional Scaling: Theory and Applications in the Behavioral Sciences* Volume 1: Theory. ed. by R.N.Shepard, A.K.Romney, and S.B.Nerlove. New York: Seminar Press, 1972.

Carroll, J.D. and Chang, J.-J. An analysis of individual differences in multidimensional scaling via an N-way generalization of "Eckart-Young" decomposition. Psychometrika, 1970, 35, 283-319.

Carroll, J.D. and Wish, M. Multidimensional perceptual models and measurement methods. in Handbook of Perception Volume II: Psychophysical Judgment and Measurement. ed. by E.C. Carterette and M.P. Friedman. New York: Academic Press, 1974.

Clark, Andrew K. Re-evaluation of Monte Carlo studies in nonmetric multidimensional scaling. Psychometrika, 1976, 41, 401-403.

Cohen, Harvey S. and Jones, Lawrence E. The effects of random error and subsampling of dimensions on recovery of configurations by non-metric multidimensional scaling. Psychometrika, 1974, 39, 69-90.

Cronbach, Lee J. Test Validation. in Educational Measurement. second edition, ed. by R.L. Thorndike. Washington: American Council on Education, 1971.

Davis, J. Kent. Strategy development and hypothesis testing as a function of an individual's cognitive style. Final report, U. S. Office of Education Project 1-E-067 (ERIC #071010), November, 1972.

DiVesta, Francis, and Dick, Walter. The test-retest reliability of children's ratings on the semantic differential. Educational and Psychological Measurement, 1966, 26, 605-616.

Evanechko, Peter O. and Maguire, Thomas O. The dimensions of children's meaning space. American Educational Research Journal, 1972, 9, 507,523.

Ferguson, George A. Statistical Analysis in Psychology and Education. Third edition. New York: McGraw-Hill, 1971.

Fiedler, F. A Theory of Leadership Effectiveness. New York: McGraw-Hill, 1967.

Field, T.W. and Cropley, A.J. Cognitive style and science achievement. Journal of Research in Science Teaching, 1969, 6, 2-10.

Fleishman, J.J. and Dusek, R. Reliability and learning factors associated with cognitive tests.

Psychological Reports, 1971, 29, 523-530.

French, J.R., Ekstorm, R.N., and Price, L. Kit of Reference Tests for Cognitive Factors. Princeton, N.J.: Educational Testing Service, 1965.

Gardner, Riley W. Reliability of group-test scores for cognitive controls and intellectual abilities over a one-year period. Perceptual and Motor Skills, 1973, 36, 753-754.

Gardner, R.W. and Lohrenz, W. Some old and new group tests of cognitive controls and intellectual abilities. Perceptual and Motor Skills, 1969, 29, 935-950.

Gardner, R.W. and Schoen, R.A. Differentiation and abstraction in concept formation. Psychological Monographs, 1962, 76, whole # 560.

Garskof, B.E., and Houston, J.P. Measurement of verbal relatedness: an idiographic approach. Psychological Review, 1963, 70, 277-288.

Hammond, Allen. Assessment context in relation to physics achievement and cognitive style. Unpublished Ph. D. dissertation, University of Alberta, 1976.

Harary, F., Norman, R.Z., and Cartwright, D. Structural Models: an introduction to the theory of directed graphs. New York: John Wiley and Sons, 1965.

Hartnett, Barbara M., and Rumery, Robert E. Markov Chain analysis of classroom interaction data. A paper presented to the annual meeting of the American Educational Research Association. New Orleans, 1973.

Harvey, O.J. Conceptual systems and attitude change. In Attitude, Ego-Involvement, and Change. ed. by C.W. Sherif and M. Sherif. New York: John Wiley and Sons, 1967.

Harvey, O.J., Hunt, D.E., and Schroder, H. Conceptual Systems and Personality Organization. New York: John Wiley and Sons, 1961.

Heise, David R. Semantic differential profiles for 1000 most frequent English words. Psychological Monographs, 1965, 79, whole #601.

Heise, David R. Some methodological issues in semantic differential research. Psychological Bulletin, 1969, 72, 406-422.

Hobbs, Edward D. *Formal operations in secondary students: a test of the idea of intellectual structural limitations.* Unpublished Ph. D. dissertation. University of Alberta, 1975.

Holzman, P.S. Scanning: a principle of reality contact. *Perceptual and Motor Skills,* 1966, *23,* 835-844.

Hunt, David E. *Matching Models in Education: the Coordination of Teaching Methods with Student Characteristics.* Monograph No. 10, Ontario Institute for Studies in Education. Toronto, 1971.

Inhelder, Barbel, and Piaget, Jean *The Growth of Logical Thinking from Childhood to Adolescence.* New York: Basic Books, 1958.

Isaac, P.D., and Poor, D.S. On the determination of appropriate dimensionality in data with error. *Psychometrika,* 1974, *39,* 91-109.

Jackson, D.N. and Messick, S. Individual Differences in social perception. *British Journal of Social ond Clinical Psychology,* 1963, *2,* 1-10.

Jackson, D.N., Messick, S., and Myers, C.T. Evaluation of group and individual forms of emmbedded figures measures of field independence. *Educational and Psychological Measurement,* 1964, *24,* 177-192.

Jakobovits, L. Comparitive psycholinguistics in the study of culture. *International Journal of Psychology,* 1966, *1,* 15-37.

Johnson, Paul E. Associative meaning of concepts in physics. *Journal of Educational Psychology,* 1964, *55,* 84-88.

Johnson, Paul E. Word relatedness and problem solving in high school physics. *Journal of Educational Psychology,* 1965, *56,* 217-224.

Johnson, Paul E. Some psychological aspects of subject matter structure. *Journal of Educational Psychology,* 1967, *58,* 75-83.

Johnson, P.E., Cox, D.L., and Curran, T.E. Psychological reality of physical concepts. *Psychonomic Science,* 1970, *19,* 245-246.

Johnson, Paul E., Curran, Thomas E., and Cox, David L. A model for knowledge of concepts in science. *Journal of Research in Science Teaching,* 1971, *8,* 91-95.

Johnson, Stephen C. Hierarchical clustering schemes. Psychometrika, 1967, 32, 241-254.

Kaiser, Henry F. Relating factors betwen studies based upon different individuals. Unpublished document. Bureau of Educational Research, University of Illinois, 1960.

Kaplan, Abraham. The Conduct of Enquiry. Scranton, Penn: Chandler Publ., 1964.

Karplus, R. and Lavetelli, C. The developmental theory of Piaget: Conservation. San Francisco: John Davidson Film Producers, 1969.

Kass, Heidi. The structure of perceived relations among physics concepts. Unpublished Ph.D. dissertation, University of Alberta, 1969.

Kass, Heidi. Structure in perceived relations among physics concepts. Journal of Research in Science Teaching, 1971, 8, 339-350.

Kelly, George a. Psychology of Personal Constructs. New York: Norton Books, 1955.

Klahr, David. A Monte Carlo investigation of the statistical significance of Kruskal's non-metric scaling procedure. Psychometrika, 1969, 34, 319-330.

Klein, G.S., Barr, H.L., and Wolitzky, D.L. Personality. Annual Review of Psychology, 1967, 18, 467-560.

Kruskal, Joseph B. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Psychometrika, 1964a, 29, 1-27.

Kruskal, Joseph B. Nonmetric multidimensional scaling: a numerical method. Psychometrika, 1964b, 29, 115-129.

Kruskal, Joseph B., and Carmone, Frank. How to use M-D-Scal (version 5-M) and other useful information. Bell Telephone Laboratories, Murray Hill, N.J., 1971.

Kuhn, Thomas S. The Structure of Scientific Revolutions. Second Edition. Chicago: University of Chicago Press, 1962. (1970)

Lawson, Anton. Implications of Piaget's theory for presentation of content and process. A paper presented at the annual meeting of the National Science Teachers Association. Philadelphia, 1976.

Lawson, Anton E. and Nordland, Floyd H. The factor structure of some Piagetian tasks. Journal of Research in Science Teaching, 1976, 13, 461-466.

Lawson, Anton E., and Renner, John W. A quantitative analysis of responses to Piagetian tasks and its implications for curriculum. Science Education, 1974, 58, 545-559.

Lawson, Anton E. and Renner, John W. Relationships of science subject matter and developmental levels of learners. Journal of Research in Science teaching, 1975, 12, 347-358.

Lingoes, James C. and Schonemann, Peter H. Alternative measures of fit for the Schonemann-Carroll matrix fitting algorithm. Psychometrika, 1974, 39, 423-427.

Lohrenz, Leander J. and Gardner, Riley W. Cognitive control in recall of similar visual designs vs. nonsimilar thematic materials. Perceptual and Motor Skills, 1973, 36, 627-631.

Lunzer, Eric A. Problems of formal reasoning in test situations. Cognitive Development in Children: Five Monographs of the Society for Research in Child Development. Chicago: University of Chicago Press, 1970. (original publication, 1962)

MacDonald, John. A study of the relationship between student achievement of process skills and the mode of instruction in junior high school science. Unpublished Ph.D. dissertation, University of Alberta, 1974.

Maguire, Thomas O. Semantic differential methodology for the structuring of attitudes. American Educational Research Journal, 1973, 10, 295-306.

Messick, Samuel J. Metric properties of the semantic differential. Educational and Psychological Measurement, 1957, 17, 200-206.

Messick, Samuel. The criterion problem in the evaluation of instruction: assessing possible, not just probable, intended outcomes. In The Evaluation of Instruction: Issues and Problems. ed. by M.C. Wittrock and D.E. Wiley. New York: Holt, Rinehart, and Winston, 1970.

Messick, Samuel and French, John W. Dimensions of cognitive closure. Multivariate Behavioural Research, 1975, 10, 3-16.

Miller, George A. The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.

Morgan, Kathryn P. Jerome S. Bruner's theory of knowledge: a philosophical critique. Unpub. M.Ed. thesis, University of Alberta, 1972.

Norman, Warren T. Stability characteristics of the semantic differential. American Journal of Psychology, 1959, 72, 581-584.

Osgood, Charles E. and Suci, George J. Factor analysis of meaning. Journal of Experimental Psychology, 1955, 50, 325-338.

Osgood, C.E., Suci, G.J., and Tannenbaum, P.H. The Measurement of Meaning. Urbana, Ill.: University of Illinois Press, 1957.

Preece, P.F.W. Mapping cognitive structure: a comparison of methods. Journal of Educational Psychology, 1976a, 68, 1-8.

Preece, P.F.W. Science concepts in semantic space-a multidimensional scaling study. Alberta Journal of Educational Research, 1976b, 22, 281-286.

Preece, P.F.W. A note on the comparison of cognitive structure and subject matter structure. Journal of Research in Science Teaching, 1976c, 13, 351-352.

Pruzansky, Sandra. How to use SINDSCAL: a computer program for individual differences. Unpublished document. Murray Hill, New Jersey: Bell Telephone Laboratories, 1975.

Rapoport, Amnon et al. A study of lexical graphs. Foundations of Language, 1966, 2, 338-376.

Raven, Ronald. The development of a test of Piaget's logical operations. Science Education, 1973, 57, 377-385.

Raven, Ronald and Polanski, Harold. Relationships among Piaget's logical operations, science content comprehension, critical thinking and creativity. Science Education, 1974, 58, 531-544.

Ross, John. A remark on Tucker and Messick's "points of view" analysis. Psychometrika, 1966, 31, 27-31.

Satterly, David J. Cognitive styles, spatial ability, and school achievement. Journal of Educational Psychology, 1976, 68, 36-42.

Schonemann, Peter. A generalized solution of the orthogonal Procrustes problem. Psychometrika, 1966, 31, 1-10.

Schonemann, Peter H. and Carroll, Robert M. Fitting one matrix to another under choice of a central dilation and a rigid motion. Psychometrika, 1970, 35, 245-255.

Schwab, Joseph H. The concept of the structure of a discipline. in Conflicting Conceptions of Curriculum. ed. by E.W.Eisner and E. Vallance Berkeley, Calif: McCutcheon Publ., 1974.

Scott, William A. Cognitive complexity and cognitive flexibility. Sociometry, 1962, 25, 405-414.

Seaman, Jerrol M., and Koenig, Frederick. A comparison of measures of cognitive complexity. Sociometry, 1974, 37, 375-390.

Shavelson, Richard J. Some aspects of the relationship between content structure and cognitive structure in physics instruction. Unpublished Ph.D. dissertation, Stanford University, 1970.

Shavelson, Richard J. Some aspects of the correspondence between content structure and cognitive structure in physics instruction. Journal of Educational Psychology, 1972, 63, 225-234.

Shavelson, Richard J. Learning from physics instruction. Journal of Research in Science Teaching, 1973, 10, 101-111.

Shavelson, Richard J. Methods for examining representation of a subject matter structure in a student's memory. Journal of Research in Science Teaching, 1974, 11, 231-250.

Shavelson, R.J. and Geeslin, W.E. A method for examining subject matter structure in written material. Journal of Structural Learning, 1975, 4, 199-218.

Shavelson, R.J. and Stanton, G.C. Construct validation: methodology and application to three measures of cognitive structure. Journal of Educational

Measurement, 1975, 12, 67-86.

Shepard, Roger S. The analysis of proximities: multidimensional scaling with an unknown distance function - I. Psychometrika, 1962a, 27, 125-139.

Shepard, Roger S. The analysis of proximities: multidimensional scaling with an unknown distance function - II. Psychometrika, 1962b, 27, 219-245.

Siegel, Sidney. Non-Parametric Statistics. New York: McGraw-Hill, 1956.

Simpson, Ronald D., Shrum, John W., and Rentz, R. Robert. The science support scale: its appropriateness with high school students. Journal of Research in Science Teaching, 1972, 9, 123-126.

Smith, S., and Leach, C. A hierarchical measure of cognitive complexity. British Journal of Psychology, 1972, 63, 561-568.

Spence, Ian and Domoney, Dennis. Single subject incomplete designs for non-metric multidimensional scaling. Psychometrika, 1974, 39, 469-490.

Spence, Ian and Graef, Jed. The determination of the underlying dimensionaltiy of an empirically obtained matrix of proximities. Multivariate Behavioral Research, 1974, 9, 331-341.

Subkoviak, Michael J. The use of multidimensional scaling in educational research. Review of Educational Research, 1975, 45, 387-423.

Tanaka, Y.A. and Osgood, C.E. Cross-culture, cross-concept, and cross-subject generality of affective meaning systems. Journal of Personality and Social Psychology, 1965, 2, 143-153.

Torgerson, Warren S. Theory and Methods of Scaling. New York: Wiley, 1958.

Triandis, H.C. and Osgood, C.E. A comparative factorial analysis of semantic structure in monolingual Greek and American college students. Journal of Abnormal and Social Psychology, 1958, 57, 187-196.

Tucker, L.R. and Messick, S. An individual differences model for multidimensional scaling. Psychometrika, 1963, 28, 333-367.

Vernon, P.E. The distinctiveness of field independence.

Journal of Personality, 1972, *40*, 366-391.

Wachtel, P.L. Field-independence and psychological differentiation: reexamination. *Perceptual and Motor Skills*, 1972, *35*, 179-189.

Wagenaar, W.A. and Padmos, P. Quantitative interpretation of stress in Kruskal's multidimensional scaling technique. *British Journal of Mathematical and Statistical Psychology*, 1971, *34*, 101-110.

Wexler, Kenneth M. and Romney, A. Kimball. Individual variations in cognitive structures. In *Multidimensional Scaling: Theory and Applications in the Behavioural Sciences* Volume 2, Applications. ed. by R.N. Shepard, A.K.Romney, and S.B. Nerlove. New York: Academic Press, 1972.

Wiggins, Nancy, and Fishbein, Martin. Dimensions of semantic space: a problem of individual differences. In *Semantic Differential Technique: a Sourcebook.* ed. by J.G. Snider and C.E. Osgood. Chicago: Aldine Publ., 1969.

Wish, M. and Carroll, J.D. Applications of individual differences scaling to studies of human perception and judgment. in *Handbook of Perception, Vol II: Psychophysical Judgment and Measurement.* ed. by E.C. Carterette and M.P.Friedman. New York: Academic Press, 1974.

Witkin, H.A. Individual differences in ease of perception of embedded figures. *Journal of Personality*, 1950, *19*, 1-15.

Witkin, H.A. *et al* *Psychological Differentiation.* New York: John Wiley and Sons, 1962.

APPENDIX A

CONSTRAINED ASSOCIATION TEST

NAME____________________

OFFICE USE ONLY

OFFICE USE ONLY

PLEASE DO NOT TURN THE PAGE UNTIL ASKED TO DO SO.

This booklet contains a word association test. It has no correct answers, and does not count for course credit. I need your name only to be able to match this test with the others you are doing. Your name will not be used in any reporting of the results.

At the top of each page there is a word in capitals, followed by a column of the same word and a column of blanks. For example:

ATOM

atom________________

atom________________

All of the words at the tops of the pages are concerned with science. Your job is to print words in the blanks which come to mind when you think of the scientific meaning of the word at the top of the page. You put down as many responses as you can in one minute. You are not expected to fill all the blanks, but write as many words as you can. I will tell you when each minute is up.

Suppose, in the example above, when you read "atom", you first thought of "molecule". You would put molecule in the first space. Please do so now. Be sure to print. Suppose that you next think of "element" in response to "atom". You would write "element" in the second space.

Don't try to think of "good" words. Just concentrate on what the word at the top of the page means in science and put down responses which come to mind.

There will be some repeated pages. Please try to answer the second time without trying to remember what you wrote the first time.

CONCLUSION

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

conclusion____________________

SIMILARITY JUDGMENT TEST

NAME____________________

OFFICE USE ONLY

On this task, I need your name only to be able to match the results with the other tasks you are doing. The results will only be used without your name.

On these pages are lists of pairs of words which you are to judge on a scale from "closely related", on the left, to "unrelated", on the right. Each item looks like this:

COUCH
SOFA
CLOSELY RELATED ____________________________________ UNRELAT.

If you feel that these words are closely related, you put a mark on the left side of the line. The further to the left you put the mark, the more closely related you feel the words are. Here's another example:

FRIEND
TOMATO
CLOSELY RELATED ____________________________________ UNRELATED

If you feel that these words are unrelated, you put a mark towards the right hand side of the line. The more unrelated you feel the words are, the more to the right your mark should go.

If you get a pair of words which are partly related, you would put a mark somewhere near the middle of the line, depending on how related you feel the words are. For example:

CHAIR
TABLE
CLOSELY RELATED ____________________________________ UNRELATED

The words on the next few pages have to do with science. Work quickly, first impressions are important. Do not turn back to a page after you have finished it. When you finish, please be quiet so others can concentrate. There will be some repeats in the task. Please do them again without trying to recall your first answer.

THERE ARE QUESTIONS ON BOTH SIDES OF THE PAGES

CLOSELY RELATED — DISCOVERY / EVIDENCE — UNRELATED
____

PUZZLE
EVIDENCE
____

EVIDENCE
INVESTIGATION
____

LAW
EVIDENCE
____

INTERPRETATION
QUESTION
____

PROOF
INTERPRETATION
____

HYPOTHESIS
INVESTIGATION
____

QUESTION
EXPLANATION
____

LAW
THEORY
____

PUZZLE
PROOF
____

SEMANTIC DIFFERENTIAL TEST

NAME________________

OFFICE USE ONLY

___.___.___.___.___.___.___

DO NOT TURN THE PAGE UNTIL ASKED TO DO SO.

The task on these pages may strike you as strange. Please try your best, even though the judgements I ask you to make seem impossible. The purpose of the task is to find out what kinds of feelings words cause in people. I need your name only to match this task with the others you are doing. I will not use your name when I report the results.

At the top of the page is a KEYWORD. Underneath is a series of 12 scales each marked off in seven intervals. Here is an example of the top of a page with one scale shown:

ATOM

extremely quite slightly neutral slightly quite extremely

ugly____.____.____.____.____.____.____beautiful

The seven segments on the line correspond to the labels directly above them. Your job is to rate the word at the top of the page on each of the 12 scales. For example, if you felt that ATOM was slightly beautiful, you would put a mark on the line below "slightly" on the "beautiful" side of the scale, the right hand side. Do so now please.

Work down each page, responding to each of the scales. There are no correct answers, so don't worry about your responses. Work quickly, first impressions are important. There will be some repeated pages. Please answer the second time without trying to remember your first answer. There are questions on BOTH sides of the page. When you finish, be quiet so that others may concentrate.

IMAGINATION

extremely quite slightly neutral slightly quite extremely

light____.____.____.____.____.____.____heavy

large____.____.____.____.____.____.____small

good____.____.____.____.____.____.____bad

unpleasant____.____.____.____.____.____.____pleasant

passive____.____.____.____.____.____.____active

weak____.____.____.____.____.____.____strong

sharp____.____.____.____.____.____.____dull

slow____.____.____.____.____.____.____fast

uncertain____.____.____.____.____.____.____certain

idea____.____.____.____.____.____.____thing

physical____.____.____.____.____.____.____mental

unfair____.____.____.____.____.____.____fair

DEVELOPMENTAL LEVEL TEST

NAME ____________________

OFFICE USE ONLY

____

____

____

DO NOT TURN THE PAGE UNTIL ASKED TO DO SO.

This test contains a series of questions designed to find out how you think. This is not a test, and it does not count for any course grade. I need your name only to match this booklet with the other tasks which you are doing. The results will only be used without your name.

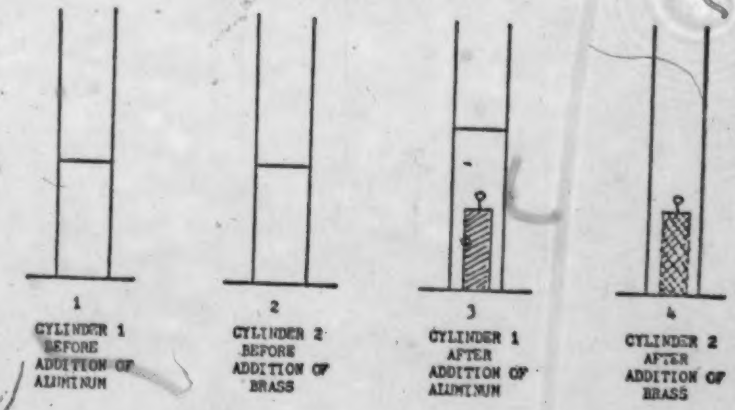
I am interested in the answers you give, but for some of the questions, I am more interested in how you arrived at your answer. It is very important that, when you are asked to explain your reasoning, you do so as carefully as you can. When you are explaining your reasoning, you may use words, calculations, or diagrams, as you wish.

When you have finished a page, do not go back to it. When you have finished all the test, please be quiet so that others can concentrate.

THERE ARE QUESTIONS ON BOTH SIDES OF THE PAGE.

THE TWO SOLIDS

Watch the demonstration at the front of the room. DO NOT WRITE ANYTHING UNTIL ASKED TO DO SO.


1
CYLINDER 1
BEFORE
ADDITION OF
ALUMINUM
2
CYLINDER 2
BEFORE
ADDITION OF
BRASS
3
CYLINDER 1
AFTER
ADDITION OF
ALUMINUM
4
CYLINDER 2
AFTER
ADDITION OF
BRASS

1. In diagram 4, mark the height you predict the water will be after the addition of the brass to cylinder 2.

2. Explain, briefly but carefully, how you figured out the answer to question 1.

AFTER YOU HAVE SEEN THE FULL DEMONSTRATION, PLEASE DO NOT CHANGE YOUR ANSWERS.
DO NOT TURN THE PAGE UNTIL ASKED TO DO SO.

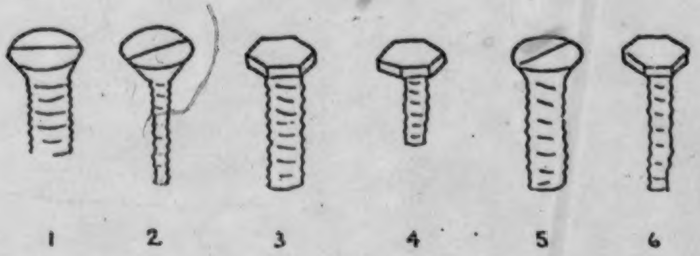
THE HAMBURGERS

When you buy a hamburger, you can get any of: ketchup (K)
relish (R)
cheese (C)
onions (O)

In this question, order does not count. Putting on ketchup and relish is the same as putting on relish and ketchup. Figure out and write down, one to a space, all the different ways you can put together a hamburger. Use the initials I have given you (K,R,C, and O) to save time and space. Remember, you don't have to have all four garnishes on each hamburger.

THE SCREWS

Look at the screws on this page. The screws differ in length, thickness, and in the shape of the head.

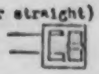
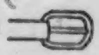


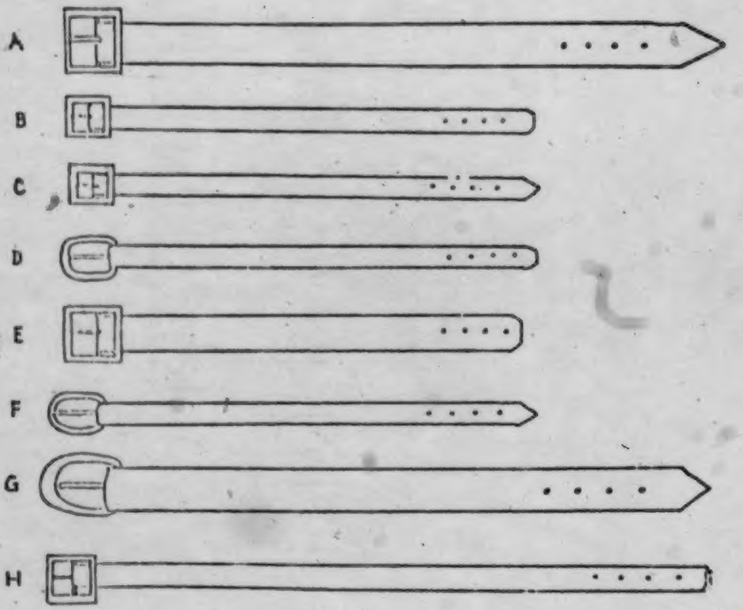
Suppose you have available a machine to test the strength of screws. The machine can only test two screws at a time.

6. Which two screws would you pick to test the statement: "The length of a screw makes a difference to the strength of the screw"? _____ and _____
7. Which two screws would you pick to test the statement: "The shape of the head of the screw makes a difference to the strength of the screw"? _____ and _____
8. Which two screws would you pich to test the statement: "The thickness of a screw makes a difference to the strength of the screw"? _____ and _____

THE BELTS

Look at the belts on this page. The belts differ as follows:

(a) in length
(b) in width
(c) in shape at the end (pointed or straight)
(d) in shape of the buckle (square  or round ).



Pick out a pair which are different from each other:

(a) in one way ONLY ______ and ______; another pair ______ and ______
(b) in two ways ONLY ______ and ______; another pair ______ and ______
(c) in three ways ONLY______ and ______; another pair ______ and ______
(d) in ALL four ways ______ and ______; another pair ______ and ______

COGNITIVE COMPLEXITY TEST

PLEASE DO NOT TURN OVER THE PAGE UNTIL ASKED TO DO SO. THANK YOU.

On the back of this page, there is a grid with six rows and six columns. The columns are lettered and the rows are numbered. There are no correct answers for this task. I need your name only to match this task with the others you are doing. I will not use your name when reporting the results. In this task, you will be asked to rate six people you know on six characteristics. I am not going to ask for the names of these people in order to protect your privacy and theirs.

Please think of six people you know who fit the following categories:

A. A good friend of the same sex as yourself.
B. A teacher from this year or last whom you find hard to like.
C. A good friend of the opposite sex from yourself.
D. A person (close to your age) of the opposite sex from yourself whom you find hard to like.
E. Your favourite teacher from this year or last.
F. A person (close to your age) of the same sex as yourself whom you find hard to like.

What you are asked to do is to read the characteristic beside each line of the grid and rate the six people on that characteristic. IT IS IMPORTANT THAT YOU WORK ACROSS THE GRID AND NOT DOWN. For example, suppose you are asked to rate each of the six people on the characteristic "interested in others(5)-interested in self(1)". If you felt that person B was very interested in others, you would put a "5" in the B box. If you felt that person F was very interested in himself, you would put a "1" in the F box. If you felt that person C was just about in the middle, you would put a "3" in the C box. Your responses would look like this:

A	B	C	D	E	F	
	5	3			1	1. Interested in others(5)-interested in self(1)

You don't have to use all the numbers between 1 and 5 if you feel you don't need to. You can use a number more than once if you wish.

When you have filled in one line completely, go on to the next one. REMEMBER, WORK ACROSS, NOT DOWN. When you have finished, please be quiet so that others can concentrate.

NAME____________________

SCHOOL____________________

GRADE____________________

AGE__________

SEX MALE_____ FEMALE_____

OFFICE USE ONLY

____

____

____

A. A good friend of the same sex as yourself.
B. A teacher from this year or last whom you find hard to like.
C. A good friend of the opposite sex from yourself.
D. A person (close to your age) of the opposite sex from yourself whom you find hard to like.
E. Your favourite teacher from this year or last.
F. A person (close to your age) of the same sex as yourself whom you find hard to like.

A	B	C	D	E	F	
						1. Outgoing(5)-Shy(1)
						2. Decisive(5)-Indecisive(1)
						3. Friendly(5)-Unfriendly(1)
						4. Cheerful(5)-Illhumoured(1)
						5. Dominant(5)-Submissive(1)
						6. Considerate(5)-Inconsiderate(1)

APPENDIX B

TABLE XXIII

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAU9

SUBJECT	DIMENSION			
ID.	1	2	3	4
1	0.50	-0.91	1.02	0.14
2	-1.20	-0.18	-0.23	-1.27
3	0.33	0.14	0.37	0.38
4	1.57	-1.78	-0.56	-1.40
5	-0.58	-1.20	0.60	0.96
6	-0.37	1.24	-2.75	0.38
7	-1.49	0.38	0.48	-1.02
8	-1.02	1.13	-2.11	-0.63
9	0.53	-1.61	-1.47	-1.16
10	0.58	0.44	2.15	1.68
11	-1.82	-0.22	-0.05	0.83
12	0.19	0.18	-0.25	-1.85
13	0.21	-1.16	-1.67	0.13
14	-0.34	-0.90	0.44	0.01
15	0.83	-0.78	0.29	-1.33
16	1.09	-1.12	1.30	-0.23
17	0.01	-0.50	0.06	0.59
18	-0.16	-0.02	0.10	-0.13
19	-0.60	-0.41	-0.25	-1.02
20	0.38	-1.21	0.66	-0.88
21	-0.59	-0.54	0.51	0.76
22	-0.33	-1.14	0.14	-0.45
23	0.45	-0.62	-0.64	-0.95
24	-0.30	-0.57	0.65	0.66
25	-0.55	-0.84	0.19	0.09
26	-0.49	-0.17	0.67	0.05
27	-0.10	-2.17	-0.32	-2.09
28	0.24	-0.51	-0.00	-0.57
29	-0.61	-1.07	0.34	-0.41
30	-0.26	-0.25	0.58	0.44
31	-1.11	-1.07	0.74	1.57
32	-0.55	0.46	0.50	-0.66
33	-0.11	-0.50	0.35	-1.49
34	-0.36	0.74	0.26	-0.58
35	-0.60	-0.66	0.12	0.96
36	-1.52	-0.59	0.10	0.12
37	-0.64	1.35	0.46	-1.24
38	1.92	-0.36	-0.71	-0.34
39	0.69	1.04	0.36	1.52
40	0.10	-1.47	1.93	1.23

TABLE XXIII (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAU9

SUBJECT	DIMENSION			
ID.	1	2	3	4
41	-0.35	-0.02	-0.77	0.66
42	-1.18	1.22	-0.48	0.67
43	-0.85	3.07	0.78	-0.45
44	-0.37	-0.52	-0.46	-1.08
45	0.47	0.49	-1.76	-0.31
46	-0.38	1.12	1.38	-1.44
47	0.97	-1.94	-1.03	-0.17
48	-0.24	0.80	0.29	-0.19
49	0.14	3.20	-1.76	-0.75
50	-0.27	1.39	-0.59	1.70
51	4.29	0.82	0.69	2.87
52	-1.38	-0.34	0.18	-0.28
53	-0.63	1.38	0.62	-1.58
54	0.32	-0.85	-1.60	1.82
55	0.42	-0.38	0.94	-0.29
56	-1.40	0.04	0.11	1.46
57	-1.91	-0.18	-2.01	1.80
58	-1.88	0.04	-0.49	1.09
59	-0.49	-0.27	0.79	0.18
60	-0.86	-0.88	0.65	0.31
61	-2.04	-0.33	0.20	1.63
62	-1.11	0.25	-0.59	-0.60
63	-0.50	1.12	0.24	-1.39
64	-1.46	-0.52	-0.62	0.94
65	-1.56	-0.73	0.85	0.96
66	-0.93	-0.48	0.51	0.35
67	-0.66	-0.62	-0.43	-0.66
68	-1.04	-0.47	-0.08	0.59
69	-0.80	-0.56	0.05	0.58
70	-1.06	-1.10	0.48	-0.81
71	-0.60	1.44	4.46	-1.12
72	0.80	0.96	0.31	0.70
73	-0.73	-1.15	-0.17	-0.52
74	0.39	0.76	-0.36	0.25
75	-0.44	0.14	0.78	0.53
76	-0.66	-0.50	-0.11	0.29
77	-0.79	0.09	0.09	-0.63
78	-0.67	-0.10	-0.15	-0.31

TABLE XXIV

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAU12

SUBJECT ID.	DIMENSION 1	2	3	4
1	0.36	0.13	-0.24	-0.22
2	0.36	0.84	-0.50	0.00
3	0.12	0.65	-0.02	-0.33
4	0.92	0.30	0.02	0.73
5	-0.30	0.48	-0.66	0.25
6	0.29	-0.05	0.10	0.01
7	0.69	0.41	-0.08	0.81
8	0.33	0.79	-0.00	0.50
9	1.53	0.36	-1.22	-0.38
10	0.30	0.17	-0.25	0.14
11	1.90	-1.16	1.57	1.58
12	0.94	0.19	-0.17	0.05
13	0.97	0.20	0.24	1.88
14	-0.05	1.08	0.86	-2.05
15	0.66	-0.02	-1.02	-0.09
16	0.38	-0.49	-0.98	-0.58
17	1.83	0.44	0.65	-0.85
18	0.95	0.24	0.41	0.11
19	-0.33	2.68	-1.99	2.19
20	0.42	-0.42	0.95	-0.52
21	-0.02	-1.52	-0.96	-0.16
22	0.77	1.76	1.44	-2.67
23	0.17	-1.03	1.12	1.14
24	-0.69	-1.63	-1.18	0.42
25	-0.61	1.61	0.67	1.49
26	1.02	0.09	-0.21	-0.37
27	1.99	-0.20	-0.78	0.38
28	0.65	0.13	-0.02	0.61
29	0.84	0.24	-0.45	-1.05
30	-1.37	2.72	-0.29	-0.92
31	1.29	0.04	0.08	-0.39
32	-1.16	0.76	3.06	0.62
33	-2.55	-1.10	0.19	0.66
34	1.40	0.86	-0.71	1.82
35	0.22	0.11	-0.26	-0.73
36	0.74	0.77	0.07	-0.10
37	-1.60	-0.09	1.77	-0.89
38	-0.17	0.25	0.17	-0.17
39	1.09	-2.41	1.84	0.52
40	1.94	0.58	-0.61	0.06

TABLE XXIV (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAU12

SUBJECT ID.	DIMENSION 1	2	3	4
41	0.35	-0.55	1.08	-1.16
42	1.70	0.11	0.43	-0.78
43	0.22	1.13	-0.63	-0.55
44	-0.71	-0.10	-2.38	-2.06
45	0.68	-0.44	-0.18	-0.70
46	1.10	-1.20	-0.78	-0.01
47	1.20	0.25	1.90	0.59
48	0.74	0.16	-0.93	-0.89
49	-0.80	-2.27	-1.50	0.61
50	0.29	1.44	0.70	0.69
51	0.00	-1.09	0.43	-2.49
52	0.15	0.29	0.96	0.32
53	0.62	0.19	-0.28	-0.36
54	1.29	-0.84	-0.76	-1.02

TABLE XXV

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS9

SUBJECT	DIMENSION			
ID.	1	2	3	4
1	1.00	-0.87	-0.62	-0.57
2	1.00	0.06	0.61	-0.06
3	1.00	-0.71	-0.24	-0.72
4	0.99	-2.10	-0.76	0.72
5	1.00	0.67	-2.47	-0.13
6	1.00	0.20	1.15	-0.10
7	1.00	0.61	1.11	-0.24
8	1.00	0.04	0.96	-0.90
9	1.00	-0.78	-0.63	-0.54
10	1.00	-0.05	-0.40	-1.15
11	1.01	2.03	0.41	0.91
12	1.00	-0.54	0.49	-0.80
13	1.00	-0.63	0.21	-0.03
14	1.00	-0.18	0.22	0.36
15	1.00	-0.96	-0.03	-0.25
16	1.00	-1.02	-1.43	-1.56
17	1.00	0.10	-0.46	-0.72
18	0.99	-0.36	0.03	1.00
19	1.00	-1.23	0.68	1.11
20	1.00	-1.82	-1.28	-0.04
21	1.00	1.07	-1.12	-0.42
22	1.00	-0.76	-1.25	2.10
23	0.99	-2.69	-0.26	0.19
24	1.00	0.51	-1.83	-1.73
25	1.00	-0.15	-1.01	-0.28
26	1.00	0.20	-0.37	0.02
27	1.00	-2.10	-0.77	1.26
28	1.00	-1.68	-0.33	0.20
29	1.00	-0.31	-0.46	0.08
30	1.00	0.21	-1.49	-2.53
31	1.00	1.41	-0.94	0.02
32	1.00	-0.17	-0.13	-1.28
33	1.00	-1.04	-0.36	-1.20
34	1.00	-0.09	1.42	-0.12
35	1.00	0.63	-1.31	-1.27
36	1.01	1.32	-0.18	0.50
37	1.00	-0.24	1.20	-0.92
38	1.00	-0.98	0.15	0.02
39	1.00	0.46	0.97	0.23
40	1.00	-0.03	-0.75	-0.03

TABLE XXV (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS9

SUBJECT ID.	DIMENSION 1	2	3	4
41	1.00	-0.06	0.05	0.20
42	1.00	0.51	0.95	-0.22
43	1.00	0.42	1.73	-0.64
44	1.00	-0.81	0.63	-0.23
45	1.00	-0.53	0.49	1.75
46	1.00	-0.45	1.32	-0.48
47	1.00	-1.35	-1.44	1.51
48	1.00	-0.28	1.78	-0.40
49	1.00	-0.05	2.35	-0.17
50	1.00	0.37	1.00	-0.35
51	0.99	-1.18	-0.73	-2.12
52	1.01	0.84	0.41	1.11
53	1.00	-0.41	1.64	-0.78
54	1.00	0.11	0.06	-0.75
55	1.00	-0.88	0.21	-0.82
56	1.00	2.05	0.49	0.39
57	1.00	1.45	0.78	0.35
58	1.01	2.03	0.52	0.32
59	1.00	0.33	0.63	-0.20
60	1.00	1.18	-2.12	0.20
61	1.01	2.25	-0.49	-0.90
62	1.01	0.42	1.26	0.34
63	1.00	-0.42	2.30	-0.23
64	1.00	1.21	0.20	-0.63
65	1.00	1.99	-1.48	-0.33
66	1.00	1.05	-0.85	1.04
67	1.00	-0.58	-0.32	2.52
68	1.00	1.69	-1.00	0.69
69	1.00	0.58	0.35	0.80
70	1.00	-0.07	-1.21	1.27
71	1.00	-0.12	0.19	-1.35
72	0.99	-0.84	0.79	-0.30
73	1.00	-0.32	-0.19	2.49
74	1.00	0.20	0.54	0.41
75	1.00	0.54	-0.27	-0.79
76	1.00	0.83	-0.77	2.51
77	1.00	-0.12	1.15	0.63
78	1.00	0.23	0.31	1.98

TABLE XXVI

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS12

SUBJECT ID.	DIMENSION 1	2	3	4
1	1.00	-0.34	0.11	0.97
2	1.00	0.62	1.24	1.76
3	1.00	1.34	0.39	-0.30
4	1.00	-0.30	1.46	-0.44
5	1.00	1.14	-0.44	1.97
6	1.00	0.35	-1.03	-1.06
7	1.00	-0.02	1.37	-1.42
8	1.00	1.28	0.74	-0.10
9	1.00	-1.23	0.59	1.62
10	1.00	-0.06	0.96	-1.64
11	1.00	-0.63	-0.22	-0.87
12	1.00	0.21	-0.01	-2.05
13	1.00	0.24	0.62	-0.51
14	1.00	1.30	-0.97	0.81
15	1.00	-1.27	0.23	1.14
16	1.00	-0.72	-0.50	0.42
17	1.01	-0.94	0.44	-0.58
18	1.00	-0.25	0.62	-1.98
19	1.00	1.28	1.15	0.77
20	1.00	0.58	-2.42	-1.04
21	1.00	-1.29	-0.68	-0.22
22	1.00	1.03	-0.31	0.15
23	1.00	0.01	-0.57	-0.51
24	1.00	-0.28	-0.55	-0.25
25	1.00	1.67	1.18	0.24
26	1.01	-1.56	0.67	0.60
27	1.00	-1.34	1.05	-0.27
28	1.00	-0.53	0.82	-0.97
29	1.00	-0.15	-0.83	0.65
30	1.00	1.93	0.86	1.61
31	1.00	-1.29	0.59	-0.92
32	1.00	1.77	-0.38	-0.02
33	1.00	1.52	-0.90	0.27
34	1.00	-0.22	1.77	-0.76
35	1.00	-0.08	-0.54	1.44
36	1.00	0.16	1.46	0.02
37	1.00	1.28	-1.22	-0.40
38	1.00	0.55	0.23	0.18
39	1.00	-0.76	-2.09	-0.38
40	1.01	-1.21	0.94	1.05

TABLE XXVI (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS12

SUBJECT ID.	DIMENSION 1	2	3	4
41	1.00	0.12	-1.56	-0.50
42	1.00	-0.88	-0.26	-0.01
43	1.00	1.13	1.00	-0.01
44	1.00	0.14	-0.60	1.78
45	1.00	-0.57	-0.26	-1.23
46	1.00	-1.81	-0.95	0.31
47	1.00	0.20	-0.13	-0.66
48	1.00	-0.56	-0.22	1.48
49	1.00	-1.54	-0.16	-0.22
50	1.00	0.94	0.80	-0.53
51	1.00	-0.06	-3.08	0.52
52	1.00	1.55	-0.55	-1.74
53	1.00	-0.87	0.59	1.69
54	1.00	-1.52	-0.49	0.14

TABLE XXVII

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ9

SUBJECT ID.	DIMENSION 1	2	3	4
1	-0.99	1.11	1.68	0.89
2	-1.00	-1.56	0.80	-0.47
3	-1.00	-0.93	0.98	-0.24
4	-1.00	-0.18	0.77	-1.28
5	-1.00	1.56	-0.71	-1.50
6	-1.00	-1.43	1.52	-0.42
7	-1.00	-1.43	0.26	-0.61
8	-1.00	-1.26	-0.83	0.42
9	-1.00	-1.78	1.88	-0.24
10	-1.00	-0.53	-0.20	-1.97
11	-1.00	1.16	0.80	0.00
12	-1.00	-0.29	1.64	-1.26
13	-1.00	0.38	0.75	-1.43
14	-1.00	0.59	-0.08	0.81
15	-1.00	-0.96	-0.00	-0.85
16	-1.00	1.93	0.46	1.31
17	-1.00	-1.00	0.58	0.02
18	-1.00	-0.54	0.42	0.03
19	-1.00	0.06	-0.44	1.44
20	-1.00	1.82	-0.79	0.14
21	-1.00	0.90	-0.80	-0.19
22	-1.00	1.53	0.90	-1.75
23	-1.00	0.01	0.06	1.61
24	-1.00	0.41	1.40	1.79
25	-1.00	1.21	0.17	-1.58
26	-1.00	0.77	-0.29	0.27
27	-1.00	-0.63	-1.10	1.36
28	-1.00	1.65	0.53	-0.15
29	-1.00	0.65	-0.23	0.11
30	-1.00	-1.41	0.99	0.21
31	-1.00	-1.13	0.70	0.09
32	-1.00	0.30	-0.44	-1.36
33	-1.01	-0.70	-1.85	-0.79
34	-1.00	-0.68	-0.40	-1.63
35	-1.00	-0.14	0.65	-1.25
36	-1.00	0.22	-0.62	-0.67
37	-1.00	-0.02	-1.14	0.14
38	-1.00	-0.50	-1.30	-0.83
39	-1.00	-0.48	-0.62	1.79
40	-1.00	-0.50	0.82	-1.16

TABLE XXVII (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ9

SUBJECT ID.	DIMENSION 1	2	3	4
41	-1.00	0.46	-0.89	0.69
42	-1.00	-1.35	-0.38	1.41
43	-1.00	-1.11	-1.70	0.15
44	-1.00	0.11	0.42	-0.46
45	-1.00	-0.71	1.48	0.54
46	-1.00	0.91	-1.79	0.33
47	-0.99	2.02	1.88	0.80
48	-1.00	-0.73	-1.80	0.79
49	-1.01	-0.77	-0.60	-0.69
50	-1.00	0.67	0.25	1.76
51	-1.00	0.74	0.98	0.27
52	-1.00	0.11	0.94	0.25
53	-1.00	-0.01	0.0	1.19
54	-1.00	-0.44	-0.05	0.85
55	-1.00	-0.84	-0.64	0.06
56	-1.00	1.96	0.49	0.45
57	-1.00	-1.53	-0.57	1.70
58	-1.00	0.89	1.30	1.14
59	-1.00	-0.64	0.03	-0.94
60	-1.00	0.33	1.00	0.81
61	-1.00	1.31	-0.27	-0.79
62	-1.00	0.59	-0.50	-0.60
63	-1.00	-1.95	-0.24	0.86
64	-1.00	-0.75	0.56	-1.36
65	-1.00	1.71	-0.01	-0.80
66	-1.00	-0.13	-1.08	-1.29
67	-1.00	-0.88	0.64	2.42
68	-1.00	0.40	-0.23	-0.96
69	-1.00	1.31	-0.00	1.01
70	-1.00	1.05	0.98	-0.44
71	-1.00	-0.29	-1.67	-0.75
72	-1.00	0.50	-1.51	1.52
73	-1.00	0.96	-1.29	-0.26
74	-1.00	0.32	-2.37	-0.15
75	-1.00	-0.41	1.24	0.43
76	-1.00	0.46	-2.27	0.22
77	-1.00	-1.32	0.87	-0.67
78	-1.00	-0.92	-0.01	-0.22

TABLE XXVIII

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ12

SUBJECT ID.	DIMENSION 1	2	3	4
1	1.00	1.45	-0.25	-1.07
2	1.00	2.15	0.88	0.60
3	1.00	0.81	0.03	-0.38
4	1.00	-0.10	0.75	-0.24
5	1.00	-0.71	0.93	0.07
6	1.00	-1.38	0.99	0.11
7	1.00	0.12	-2.05	2.53
8	1.00	0.44	-0.09	-0.54
9	1.00	-0.52	2.28	-0.38
10	1.00	0.79	-0.89	0.22
11	1.00	-0.33	0.40	0.21
12	1.00	-0.16	0.92	1.26
13	1.00	-0.79	-0.15	-1.20
14	1.00	-0.16	0.55	0.77
15	1.00	0.96	1.16	0.31
16	1.00	-0.51	-0.37	0.41
17	1.00	-0.58	0.17	0.45
18	1.00	-1.27	1.57	-2.39
19	1.00	1.43	0.59	-1.19
20	1.00	-1.04	-0.62	0.02
21	1.00	-0.34	-0.20	-0.99
22	1.00	1.18	0.78	0.06
23	1.00	-1.07	-0.88	-0.76
24	1.00	-0.36	0.25	0.52
25	1.00	1.15	0.07	0.16
26	1.00	-0.28	1.04	-1.09
27	1.00	-1.67	1.15	1.05
28	1.00	1.85	1.03	0.16
29	1.00	-0.49	-1.13	-0.96
30	1.00	0.92	0.03	0.06
31	1.00	-1.24	-0.99	0.64
32	1.00	2.06	0.59	0.35
33	1.00	1.21	-0.36	-0.38
34	1.00	-2.22	0.38	-0.34
35	1.00	-0.07	-1.75	1.03
36	1.00	0.75	-0.70	-2.59
37	1.00	0.90	-1.86	0.56
38	1.00	1.30	0.71	1.48
39	1.00	-0.23	-1.61	-1.03
40	1.00	-0.41	-2.13	-1.05

TABLE XXVIII (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ12

SUBJECT	DIMENSION			
ID.	1	2	3	4
41	1.00	-1.58	-0.90	0.50
42	1.00	0.09	1.99	0.95
43	1.00	0.33	-0.84	0.63
44	1.00	0.51	1.01	0.10
45	1.00	-0.45	0.15	-0.35
46	0.99	0.50	-1.06	-2.71
47	1.00	-0.24	0.51	-0.08
48	1.00	0.24	-0.83	1.50
49	1.00	-2.15	0.98	0.47
50	1.00	0.20	-0.45	1.54
51	1.00	-0.78	0.44	0.82
52	1.00	-0.47	-0.78	0.35
53	1.00	0.42	-0.36	-0.83
54	1.00	-0.18	-1.14	0.69

TABLE XXIX

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD9

SUBJECT ID.	DIMENSION 1	2	3	4
1	-1.00	-0.22	0.06	-1.39
2	-1.00	0.46	0.57	-0.39
3	-1.00	0.91	0.11	0.70
4	-1.00	-1.86	0.29	-0.74
5	-1.00	-0.30	0.68	-0.97
6	-1.00	-0.43	-0.31	1.08
7	-1.00	0.64	-1.87	0.92
8	-1.00	0.54	0.53	0.01
9	-1.00	-1.41	-1.06	-2.05
10	-1.00	-0.08	-2.41	0.17
11	-1.00	1.24	0.74	-0.33
12	-1.00	0.58	0.33	1.15
13	-1.00	0.34	1.69	0.46
14	-1.00	1.79	-2.02	-0.48
15	-1.00	1.40	0.47	-1.16
16	-1.00	-0.74	-0.93	-1.49
17	-1.00	0.84	0.53	0.28
18	-1.00	-0.90	0.48	1.20
19	-1.00	-0.60	-1.68	-1.35
20	-1.00	-1.77	-0.76	-0.26
21	-1.00	0.00	0.44	0.43
22	-1.00	-0.05	0.11	-1.38
23	-1.00	0.69	1.44	0.95
24	-1.00	0.70	-0.54	0.28
25	-1.00	-0.55	-0.44	1.05
26	-1.00	0.30	-0.34	1.88
27	-1.00	-0.07	0.17	0.25
28	-1.00	0.90	-0.26	-0.39
29	-1.00	1.44	0.19	-1.46
30	-1.00	-0.47	0.69	1.13
31	-1.00	-0.23	-1.36	-0.66
32	-1.00	-1.00	-0.71	-0.57
33	-1.00	-0.03	1.96	0.14
34	-1.00	-0.64	1.03	0.53
35	-1.00	-0.63	2.05	0.66
36	-1.00	-0.92	-0.19	-0.32
37	-1.00	0.35	-1.12	1.38
38	-1.00	0.57	1.00	-1.68
39	-1.00	-0.82	-1.33	-0.40
40	-1.00	-1.64	-0.63	-0.58

TABLE XXIX (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD9

SUBJECT ID.	DIMENSION 1	2	3	4
41	-1.00	1.56	-0.69	-0.23
42	-1.00	0.34	0.90	-0.76
43	-1.00	0.77	-0.30	-0.41
44	-1.00	-0.39	1.51	0.12
45	-1.00	0.26	-0.48	1.97
46	-1.00	-0.92	0.09	0.59
47	-0.99	-2.19	-1.52	1.18
48	-1.00	-0.78	0.42	-0.77
49	-1.00	-1.41	2.29	1.27
50	-1.00	-0.78	0.09	-0.36
51	-1.00	1.71	-1.92	-1.07
52	-1.00	1.17	1.03	-0.14
53	-1.00	0.80	-0.62	0.10
54	-1.00	0.73	-0.96	0.92
55	-1.00	1.40	-1.21	1.01
56	-1.00	-1.76	-1.17	0.39
57	-1.00	0.38	0.34	-0.18
58	-1.00	-0.65	0.65	-1.96
59	-1.00	0.42	-0.88	1.74
60	-1.00	-1.73	0.21	-0.35
61	-1.00	1.58	0.19	-1.35
62	-1.00	0.24	0.03	-1.96
63	-1.00	0.53	0.32	-0.10
64	-1.00	1.30	0.69	0.35
65	-1.00	0.15	-0.49	1.12
66	-1.00	0.49	0.32	1.06
67	-1.00	-0.47	1.96	-1.08
68	-1.00	-1.08	-0.41	1.74
69	-1.00	-0.82	-0.82	-0.47
70	-1.00	-1.07	1.34	0.51
71	-1.01	1.55	0.24	0.86
72	-1.00	-1.65	-0.64	0.50
73	-1.00	1.02	0.41	1.68
74	-1.00	0.88	-0.81	-1.69
75	-1.00	0.23	1.92	-1.16
76	-1.00	1.75	0.06	0.65
77	-1.00	-1.36	-0.09	0.21
78	-1.00	-0.66	0.28	-0.58

TABLE XXX

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD12

SUBJECT	DIMENSION			
ID.	1	2	3	4
1	-1.00	-1.47	1.32	1.71
2	-1.00	-0.90	2.06	-1.08
3	-1.00	0.72	1.29	-1.74
4	-1.00	-1.88	0.29	-1.45
5	-1.00	-0.71	-1.05	-0.32
6	-1.00	-1.15	-1.86	-0.10
7	-1.00	0.75	0.64	1.53
8	-1.00	1.68	-0.66	-0.01
9	-1.00	0.78	0.45	-0.85
10	-1.00	-1.53	-0.55	-0.69
11	-1.01	-0.81	-0.18	-1.09
12	-1.00	-1.32	0.34	0.01
13	-1.00	-0.09	2.44	0.60
14	-1.00	1.07	0.60	-0.82
15	-1.00	0.50	-0.13	-0.17
16	-1.00	0.89	-0.92	0.15
17	-1.00	-0.53	-1.28	-0.41
18	-1.00	-1.12	-0.35	-0.53
19	-1.00	-0.86	1.04	-1.34
20	-1.00	0.72	-0.40	1.82
21	-1.00	-0.55	0.87	-0.47
22	-1.00	1.30	0.55	-2.19
23	-1.00	2.11	-0.08	-0.11
24	-1.00	-0.83	-0.91	0.51
25	-1.00	2.63	-0.40	-0.83
26	-1.00	0.18	0.38	2.09
27	-1.00	-0.31	-0.95	0.45
28	-1.00	0.56	-0.47	-0.41
29	-1.00	-0.23	0.29	0.77
30	-1.00	1.41	0.83	1.76
31	-1.00	-0.94	0.42	0.62
32	-1.00	0.38	-1.06	0.06
33	-1.00	0.84	-0.71	0.69
34	-1.00	-1.02	-1.17	0.92
35	-1.00	-0.46	1.16	1.14
36	-1.00	0.03	1.98	0.53
37	-1.00	-0.96	1.15	-0.32
38	-1.00	1.73	0.50	-1.61
39	-1.00	-0.43	-0.87	0.01
40	-1.00	0.18	-0.97	-0.06

TABLE XXX (CONT.)

UNROTATED LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD12

SUBJECT ID.	DIMENSION 1	2	3	4
41	-1.00	1.71	-0.88	-0.32
42	-1.00	-0.24	-0.76	-0.68
43	-1.00	1.19	1.26	0.41
44	-1.00	-0.09	-1.00	0.16
45	-1.00	-1.32	-0.73	0.92
46	-1.00	-0.00	-1.62	0.59
47	-1.00	-0.69	-0.70	-1.08
48	-1.00	-0.47	0.17	-0.52
49	-1.00	-0.00	-1.31	-0.26
50	-1.00	-0.24	-0.32	0.10
51	-1.00	-0.08	0.91	1.56
52	-1.00	0.42	0.94	1.99
53	-1.00	-0.78	1.46	-1.75
54	-1.00	0.30	-0.96	0.14

TABLE XXXI

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAU9

SUBJECT ID.	DIMENSION 1	2	3	4
1	-0.13	1.59	0.04	0.57
2	1.43	0.09	0.65	0.49
3	-0.21	0.54	0.68	0.44
4	-0.58	0.94	-0.78	2.39
5	0.93	1.15	-0.38	0.28
6	0.57	-2.51	1.18	1.63
7	1.39	0.31	1.09	-0.35
8	1.16	-1.96	1.40	1.22
9	0.57	0.19	-0.34	2.83
10	-0.61	2.07	1.61	-0.12
11	1.85	-0.02	0.31	-0.24
12	0.21	0.31	1.27	1.39
13	0.69	-0.32	-0.20	2.45
14	0.77	1.10	0.19	0.76
15	-0.21	1.20	0.43	1.53
16	-0.53	2.14	0.20	1.07
17	0.37	0.63	0.35	0.90
18	0.16	0.10	0.09	-0.04
19	0.77	0.01	-0.09	0.28
20	0.07	1.36	-0.37	0.71
21	0.71	0.71	-0.01	-0.04
22	0.72	0.76	-0.47	0.57
23	-0.10	-0.11	-0.46	0.90
24	0.42	0.83	-0.10	-0.06
25	0.83	0.63	-0.22	0.34
26	0.49	0.67	0.27	-0.25
27	0.92	0.95	-1.22	1.43
28	0.07	0.46	0.00	0.71
29	0.97	0.90	-0.25	0.44
30	0.29	0.63	0.10	-0.16
31	1.43	1.22	-0.01	0.17
32	0.52	0.43	1.12	0.01
33	0.38	0.75	0.22	0.50
34	0.28	0.10	1.23	0.06
35	0.84	0.49	-0.08	0.32
36	1.66	0.33	0.06	-0.05
37	0.32	-0.06	1.72	-0.41
38	-1.11	0.46	0.75	2.63
39	-0.70	0.30	1.61	0.54
40	0.38	2.68	0.10	0.45

TABLE XXXI (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAU9

SUBJECT ID.	DIMENSION 1	2	3	4
41	0.59	-0.42	0.38	0.82
42	0.98	-0.83	1.50	-0.04
43	0.03	-0.54	3.26	-1.12
44	0.79	0.16	0.26	1.05
45	-0.14	-1.30	0.63	1.60
46	0.11	0.92	1.89	-0.51
47	0.03	0.49	-1.08	2.32
48	0.16	0.13	1.30	0.10
49	-0.49	-2.41	3.08	0.87
50	0.21	-0.74	1.83	0.61
51	-3.75	1.43	1.82	2.47
52	1.46	0.30	0.26	-0.10
53	0.26	0.02	1.68	-0.60
54	0.52	-0.35	0.11	2.42
55	-0.08	1.42	0.75	0.74
56	1.37	0.05	0.50	-0.25
57	2.26	-1.49	0.30	1.09
58	1.90	-0.48	0.48	-0.08
59	0.59	0.93	0.46	-0.02
60	1.05	0.94	-0.23	-0.10
61	2.10	0.29	0.44	-0.26
62	1.13	-0.57	0.53	0.17
63	0.30	-0.10	1.52	-0.12
64	1.73	-0.21	0.12	0.49
65	1.65	1.00	0.10	-0.41
66	1.02	0.66	0.10	-0.15
67	0.93	-0.02	-0.23	0.48
68	1.18	0.13	-0.04	0.07
69	1.00	0.35	-0.02	0.23
70	1.35	0.94	-0.29	0.13
71	-0.13	3.32	2.85	-2.22
72	-0.91	0.10	1.12	0.21
73	1.16	0.50	-0.43	0.66
74	-0.26	-0.20	1.29	0.92
75	0.49	0.85	0.97	0.08
76	0.82	0.14	-0.18	0.17
77	0.79	0.08	0.48	-0.04
78	0.72	-0.06	0.16	0.08

TABLE XXXII

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS --CAU12

SUBJECT ID.	DIMENSION 1	2	3	4
1	-0.10	0.10	0.13	0.48
2	-0.58	0.64	-0.00	0.70
3	-0.21	0.58	-0.19	0.29
4	0.23	0.28	-0.05	1.01
5	-0.64	0.60	0.53	0.13
6	0.23	0.02	0.04	0.28
7	0.04	0.40	0.01	0.85
8	-0.14	0.78	-0.14	0.57
9	-0.62	0.01	0.50	1.95
10	-0.19	0.03	0.02	0.39
11	2.56	-0.22	0.21	1.47
12	0.13	0.15	0.09	1.06
13	0.45	0.23	-0.14	0.98
14	0.44	1.48	-0.38	0.14
15	-0.62	-0.31	0.45	0.90
16	-0.23	-0.15	1.22	0.75
17	0.86	0.27	-0.67	1.70
18	0.52	0.20	-0.35	0.88
19	-2.45	2.42	0.68	1.06
20	1.14	-0.00	-0.13	0.16
21	0.16	-0.78	1.83	0.21
22	0.87	2.06	-1.00	0.93
23	1.80	0.25	0.84	0.05
24	0.27	0.02	3.04	-0.01
25	0.22	2.51	0.23	0.03
26	0.10	-0.06	-0.02	1.08
27	0.15	-0.30	0.59	2.22
28	0.17	0.13	0.01	0.71
29	0.58	0.35	-0.21	0.82
30	-1.18	3.36	0.40	-0.20
31	0.44	-0.04	-0.11	1.27
32	2.35	2.47	-0.48	-1.28
33	0.82	1.33	2.74	-1.91
34	-0.43	0.56	0.11	1.82
35	-0.10	0.20	0.29	0.39
36	-0.03	0.58	-0.38	0.88
37	1.70	1.89	0.91	-1.41
38	0.25	0.78	0.43	0.08
39	3.12	-0.95	0.81	0.40
40	-0.17	0.11	-0.10	2.17

TABLE XXXII (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAU12

SUBJECT ID.	DIMENSION 1	2	3	4
41	1.36	0.10	0.06	0.10
42	0.85	0.11	-0.25	1.62
43	-0.77	1.03	0.15	0.75
44	-1.49	0.66	2.62	0.44
45	0.35	-0.21	0.51	0.74
46	0.31	-0.99	1.09	1.14
47	1.95	0.85	-0.70	0.90
48	-0.45	0.15	0.68	1.13
49	0.37	-0.28	3.77	-0.05
50	0.30	1.74	-0.41	0.61
51	1.09	-0.19	0.92	-0.07
52	0.78	0.59	-0.41	0.03
53	-0.07	0.13	0.13	0.77
54	0.27	-0.63	1.02	1.45

TABLE XXXIII

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS9

SUBJECT ID.	DIMENSION 1	2	3	4
1	0.48	-0.39	-0.61	-1.39
2	0.79	0.02	0.32	-0.06
3	-0.15	-0.62	-0.96	0.12
4	0.49	1.09	-1.59	-1.63
5	-2.85	-0.58	-0.22	-0.33
6	0.53	-0.06	0.15	1.17
7	1.01	-0.21	0.86	0.38
8	0.66	-0.82	-0.08	0.88
9	-0.10	-0.43	-0.85	-0.63
10	-0.90	-1.25	-0.75	0.84
11	0.14	0.61	2.40	-0.15
12	0.62	-0.63	-0.57	0.25
13	0.96	0.18	-0.20	-0.83
14	1.44	0.55	0.68	-1.66
15	0.60	-0.04	-0.75	-0.61
16	0.42	-1.36	-0.80	-2.43
17	-0.23	-0.76	-0.05	-0.33
18	-0.17	1.03	-0.26	0.16
19	0.89	1.40	-0.76	-0.04
20	0.15	0.25	-1.50	-1.95
21	-0.61	-0.66	1.06	-1.19
22	-1.24	2.06	-0.67	-0.64
23	0.64	0.68	-2.43	-0.75
24	-1.87	-2.03	-0.40	-0.24
25	-0.39	-0.31	-0.15	-1.07
26	-0.56	-0.08	0.01	0.10
27	0.44	1.62	-1.50	-1.68
28	-0.12	0.45	-1.75	-0.05
29	0.63	0.20	0.20	-1.60
30	-1.19	-2.69	-0.62	-0.39
31	-0.58	-0.27	1.50	-1.11
32	-0.63	-1.32	-0.83	0.96
33	0.17	-1.02	-1.22	-0.35
34	0.74	-0.01	-0.13	1.41
35	-1.17	-1.50	0.11	-0.47
36	-0.43	0.25	1.36	-0.11
37	0.50	-0.81	-0.56	1.56
38	0.67	0.25	-0.71	-0.47
39	0.32	0.20	0.45	1.03
40	-0.07	-0.03	0.15	-1.15

TABLE XXXIII (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS9

SUBJECT ID.	DIMENSION 1	2	3	4
41	-0.69	0.13	-0.44	1.02
42	0.14	-0.28	0.28	1.34
43	0.66	-0.62	0.16	2.03
44	1.06	0.03	-0.51	-0.18
45	-1.23	1.69	-1.04	2.28
46	1.44	-0.23	-0.17	0.44
47	-1.50	1.53	-1.55	-0.36
48	1.84	-0.13	0.13	0.58
49	0.87	-0.05	-0.32	2.79
50	0.81	-0.31	0.49	0.55
51	-0.81	-2.02	-2.05	0.59
52	-0.00	0.97	1.06	0.27
53	1.25	-0.56	-0.41	1.28
54	0.80	-0.67	0.39	-0.87
55	1.46	-0.51	-0.36	-1.30
56	0.21	0.10	2.30	-0.02
57	0.64	0.19	1.81	0.03
58	0.10	0.02	2.19	0.21
59	1.50	-0.07	1.00	-1.05
60	-2.36	-0.27	0.61	-0.60
61	-0.79	-1.34	1.93	-0.05
62	0.60	0.35	0.50	1.11
63	2.44	0.14	0.21	0.64
64	0.81	-0.72	1.59	-0.92
65	-1.97	-0.88	1.39	-0.14
66	-1.03	0.75	1.05	-0.45
67	-0.95	2.48	-0.50	0.40
68	-1.67	0.22	1.34	0.10
69	0.62	0.78	1.08	-0.56
70	-1.63	1.08	-0.36	-0.02
71	0.31	-1.28	-0.34	0.19
72	-0.08	-0.17	-1.29	1.70
73	-0.32	2.49	0.13	-0.33
74	-0.63	0.31	-0.23	1.65
75	-0.50	-0.93	0.18	0.28
76	-1.57	2.19	0.82	0.17
77	0.74	0.74	0.10	0.80
78	-0.59	1.87	0.28	0.89

TABLE XXXIV

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS12

SUBJECT ID.	DIMENSION 1	2	3	4
1	0.04	1.70	0.68	0.99
2	0.52	-0.38	1.77	1.21
3	-0.29	0.91	-0.78	2.33
4	-1.31	-0.61	0.57	0.22
5	1.90	0.24	0.82	1.08
6	0.20	-0.11	-1.45	-0.42
7	-1.64	-1.23	-0.27	-0.02
8	0.32	-2.25	0.09	0.17
9	0.22	0.13	2.06	-0.77
10	-1.89	0.43	-0.89	0.89
11	-0.41	-0.81	-0.39	-1.41
12	-1.25	-0.08	-1.70	0.15
13	-0.18	-2.19	0.15	-0.95
14	1.76	-0.54	-0.28	0.31
15	-0.15	1.38	1.32	-0.14
16	-0.01	1.80	0.10	0.25
17	-0.97	-0.08	0.16	-0.75
18	-1.74	-0.32	-1.12	-0.09
19	0.38	-1.38	0.83	1.11
20	1.17	0.46	-2.28	-0.70
21	-0.61	2.39	-0.33	-0.05
22	0.83	-0.80	-0.33	0.28
23	0.05	0.16	-0.70	-0.26
24	0.14	0.04	-0.35	-0.64
25	0.30	-2.10	0.38	0.98
26	-0.65	0.33	1.40	-0.92
27	-1.50	0.61	0.75	-0.24
28	-1.57	0.76	-0.29	0.56
29	1.18	-0.79	0.32	-1.30
30	1.11	-0.44	0.93	2.28
31	-1.57	0.59	0.00	-0.51
32	0.91	-0.45	-0.88	1.27
33	1.22	0.33	-0.91	1.22
34	-1.61	-1.04	0.50	0.19
35	0.88	1.78	0.63	0.88
36	-0.73	-1.20	0.83	0.27
37	1.25	-0.93	-1.28	-0.18
38	-0.17	1.18	-0.18	1.60
39	1.05	0.03	-0.96	-2.19
40	-0.29	-0.34	1.84	-0.88

TABLE XXXIV (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - CAS12

SUBJECT ID.	DIMENSION 1	2	3	4
41	0.83	0.12	-1.20	-0.85
42	-0.24	0.68	0.13	-0.59
43	-0.44	0.16	-0.05	1.98
44	1.45	0.81	0.93	0.35
45	-1.05	1.09	-1.03	0.03
46	0.13	0.94	0.41	-1.84
47	-0.15	-0.49	-0.59	-0.25
48	0.97	-0.05	1.31	-0.75
49	-0.55	0.24	0.37	-1.54
50	-0.29	-1.50	-0.19	0.41
51	2.31	1.14	-1.19	-1.30
52	-0.05	-0.89	-2.15	0.57
53	0.44	-0.13	2.00	-0.59
54	-0.18	0.72	0.42	-1.38

TABLE XXXV

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ9

SUBJECT	DIMENSION			
ID.	1	2	3	4
1	3.40	1.19	0.44	-0.36
2	-0.12	1.30	1.41	-0.75
3	-0.00	0.43	1.30	-0.31
4	-0.18	-0.50	0.80	-1.16
5	-0.00	-1.30	-1.33	-1.34
6	-0.59	-0.08	2.12	-0.16
7	-1.04	0.47	1.04	-0.41
8	-1.48	0.51	0.05	0.77
9	-0.47	0.20	2.58	-0.05
10	-1.09	-0.25	0.22	-1.72
11	0.91	-1.11	0.07	0.01
12	-0.38	-1.34	1.69	-0.83
13	0.90	0.12	0.34	-1.83
14	0.54	-0.14	-0.42	0.72
15	-1.66	-0.67	0.71	-0.21
16	1.66	-1.06	-0.68	1.15
17	0.39	1.31	0.89	-0.39
18	0.58	1.07	0.51	-0.40
19	-0.25	-0.18	-0.36	1.66
20	0.07	-1.68	-1.51	0.49
21	0.03	-0.45	-1.13	-0.14
22	0.48	-2.02	0.07	-1.51
23	-0.15	-0.44	0.10	1.90
24	1.90	0.39	0.78	1.29
25	0.10	-1.45	-0.39	-1.38
26	-0.03	-0.83	-0.59	0.48
27	0.81	2.64	-0.89	0.51
28	0.41	-2.14	-0.28	0.24
29	-0.41	-1.20	-0.41	0.53
30	-0.25	0.70	1.57	0.20
31	-1.19	-0.58	1.35	0.66
32	0.28	0.48	-0.61	-1.70
33	-1.75	0.45	-1.10	-0.48
34	-0.62	0.68	0.01	-1.74
35	-0.32	-0.63	0.71	-1.06
36	-1.18	-1.14	-0.45	-0.09
37	-0.02	0.98	-1.04	-0.14
38	-0.03	1.85	-1.00	-1.40
39	-0.38	0.50	-0.27	1.90
40	-0.28	-0.26	1.01	-1.05

TABLE XXXV (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ9

SUBJECT ID.	DIMENSION 1	2	3	4
41	0.33	0.48	-1.08	0.48
42	0.08	2.06	0.22	0.98
43	-1.95	0.52	-0.73	0.59
44	0.87	0.63	0.17	-0.91
45	0.66	0.42	1.55	0.34
46	-0.33	-0.11	-1.98	0.40
47	3.14	-0.53	0.30	0.05
48	-0.58	1.72	-1.24	0.54
49	-1.64	-0.41	0.07	-0.14
50	0.36	-0.86	-0.10	1.99
51	1.73	0.28	0.27	-0.29
52	-0.22	-1.25	0.87	0.69
53	0.23	0.16	-0.02	1.17
54	0.51	1.17	0.06	0.47
55	-0.17	1.45	-0.21	-0.26
56	2.21	-0.36	-0.79	-0.13
57	-1.07	1.02	0.35	1.92
58	0.37	-1.97	0.78	1.64
59	0.50	1.54	0.19	-1.54
60	0.98	-0.19	0.61	0.65
61	0.39	-0.94	-0.89	-0.77
62	-0.33	-0.69	-0.66	-0.40
63	-1.16	1.28	0.83	0.99
64	-0.97	-0.53	1.01	-0.99
65	1.46	-0.38	-1.02	-1.26
66	-1.00	0.01	-0.78	-1.12
67	0.28	0.69	0.95	2.39
68	-0.72	-1.12	-0.25	-0.54
69	1.50	-0.00	-0.83	0.59
70	0.45	-1.64	0.38	-0.17
71	-0.61	1.15	-1.32	-0.98
72	-0.62	-0.29	-1.47	1.83
73	0.19	0.10	-1.64	-0.43
74	-0.84	0.58	-2.17	-0.14
75	-0.15	-0.76	1.36	0.76
76	-0.87	0.24	-2.13	0.35
77	-0.10	0.97	1.37	-0.88
78	-1.27	-0.30	0.62	0.25

TABLE XXXVI

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ12

SUBJECT	DIMENSION			
ID.	1	2	3	4
1	-0.25	-0.93	0.77	-1.37
2	0.27	-0.81	2.29	0.04
3	-0.13	-0.12	0.62	-0.65
4	-0.71	0.07	0.23	0.27
5	-0.67	-0.99	-0.31	1.28
6	-0.86	-0.05	-0.71	1.39
7	3.22	-0.16	-0.35	0.67
8	-0.13	-1.74	-0.04	-0.08
9	-1.96	0.34	0.60	1.16
10	0.83	1.54	0.54	-1.28
11	-0.19	-0.04	-0.06	0.56
12	0.23	-0.14	0.54	1.55
13	-0.83	-1.05	-1.17	-0.18
14	0.02	2.02	0.59	0.26
15	-0.44	0.74	1.56	0.11
16	0.38	1.16	-0.36	-0.03
17	0.07	0.32	-0.28	0.62
18	-2.99	-0.30	-0.91	-0.06
19	-0.89	-1.28	1.08	-0.86
20	0.24	0.07	-1.18	0.20
21	-0.67	0.87	-0.47	-0.93
22	-0.28	0.24	1.44	-0.23
23	-0.27	2.33	-1.16	-1.25
24	0.07	0.87	0.05	0.41
25	0.26	0.32	1.11	-0.57
26	-1.53	-0.13	0.00	-0.01
27	-0.37	-0.06	-0.69	2.31
28	-0.17	-1.19	1.95	0.10
29	0.02	-0.15	-1.18	-1.00
30	0.25	-0.79	0.71	-0.17
31	0.86	0.48	-1.34	0.41
32	0.20	0.52	2.22	-0.70
33	0.15	0.98	0.95	-1.46
34	-0.96	0.50	-1.74	0.99
35	1.84	1.23	-0.49	-0.62
36	-1.12	-1.24	-0.41	-2.23
37	1.93	-1.49	-0.21	-0.61
38	0.74	1.11	1.94	0.38
39	0.36	-0.37	-1.24	-1.39
40	0.63	0.16	-1.56	-1.77

TABLE XXXVI (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SJ12

SUBJECT	DIMENSION			
ID.	1	2	3	4
41	0.57	1.68	-1.44	0.14
42	-0.70	0.24	1.26	1.67
43	1.20	-2.07	-0.28	0.50
44	-0.52	-0.02	0.94	0.37
45	-0.44	-0.00	-0.39	0.07
46	-0.96	-1.93	-0.93	-2.15
47	-0.56	1.63	0.26	-0.20
48	1.69	-0.39	0.07	0.62
49	-0.80	0.77	-1.19	1.77
50	1.51	-1.30	0.09	1.19
51	0.16	-0.50	-0.37	1.42
52	0.79	-1.71	-0.96	0.65
53	-0.27	0.25	0.05	-1.11
54	1.20	0.46	-0.48	-0.19

TABLE XXXVII

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD9

SUBJECT	DIMENSION			
ID.	1	2	3	4
1	0.17	-1.20	-0.87	-0.62
2	0.74	-0.23	-0.36	0.08
3	0.36	1.89	0.07	0.20
4	-1.19	-1.59	-0.75	0.44
5	-0.02	0.12	-1.38	0.18
6	-0.41	-0.51	1.24	0.41
7	-0.47	1.01	1.48	-1.21
8	0.87	-0.45	0.16	0.20
9	-1.60	-0.56	-1.67	-1.38
10	-0.93	-0.53	1.46	-1.83
11	1.46	0.10	-0.26	-0.01
12	0.24	1.56	0.43	0.71
13	1.20	-0.64	0.07	1.41
14	0.89	-0.08	1.13	-2.49
15	1.08	1.65	-1.56	-0.61
16	-0.93	-0.49	-1.01	-1.23
17	0.80	0.77	-0.04	0.30
18	-0.82	0.51	0.37	1.33
19	-1.12	-0.46	-0.50	-1.81
20	-2.05	0.17	-0.59	-0.09
21	-0.20	1.33	-0.39	0.63
22	-0.08	0.33	-1.51	-0.56
23	1.12	0.44	0.28	1.39
24	0.42	0.07	0.71	-0.53
25	-0.87	0.55	0.75	0.39
26	-0.09	0.72	1.69	0.59
27	-0.48	1.69	-0.63	0.37
28	0.17	2.05	-0.86	-0.62
29	1.39	0.27	-1.08	-1.06
30	-0.19	0.05	0.56	1.27
31	-0.69	-0.31	0.06	-1.34
32	-1.00	-0.87	-0.17	-0.53
33	1.31	-1.82	0.04	1.54
34	0.12	-1.09	0.29	1.25
35	0.64	-1.39	0.10	2.11
36	-0.86	-0.33	-0.39	0.01
37	-0.94	2.78	0.67	-0.19
38	0.70	0.99	-2.28	-0.19
39	-1.18	-0.55	0.19	-0.99
40	-1.40	-1.47	-0.16	-0.27

TABLE XXXVII (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD9

SUBJECT ID.	DIMENSION 1	2	3	4
41	1.45	-0.88	1.04	-1.27
42	1.03	-1.16	-0.48	0.16
43	1.03	-1.49	0.69	-0.79
44	0.54	-0.99	-0.26	1.35
45	-0.30	1.14	1.64	0.56
46	-0.56	-1.00	0.64	0.64
47	-2.73	-0.02	1.04	0.16
48	0.04	-2.10	-0.24	0.13
49	-0.40	0.03	-0.36	2.95
50	-0.25	-1.57	0.06	0.10
51	0.97	-0.47	0.67	-2.69
52	1.31	0.82	-0.56	0.37
53	0.23	0.97	0.21	-0.68
54	0.44	-0.53	1.79	-0.60
55	0.80	0.04	1.95	-0.96
56	-2.02	-0.54	0.53	-0.13
57	0.52	-0.06	-0.16	0.04
58	-0.16	-0.55	-2.10	-0.24
59	-0.05	0.20	2.09	0.01
60	-1.46	-0.32	-0.88	0.60
61	1.95	-1.22	-0.25	-1.14
62	-0.11	1.32	-2.36	-0.96
63	0.63	0.05	-0.07	0.02
64	1.46	0.21	0.37	0.27
65	-0.19	0.42	1.13	0.13
66	0.43	0.54	0.78	0.63
67	0.44	-0.19	-1.98	1.18
68	-1.71	1.73	0.66	1.01
69	-1.14	0.05	-0.37	-0.59
70	-0.04	-1.50	0.17	1.62
71	0.95	2.17	0.25	0.17
72	-1.95	0.39	0.01	0.35
73	0.92	0.71	1.42	0.83
74	0.54	-0.08	-0.87	-1.80
75	0.88	0.54	-2.13	0.90
76	1.68	0.01	1.18	-0.26
77	-1.18	-0.55	0.02	0.49
78	-0.31	-0.67	-0.59	0.14

TABLE XXXVIII

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD12

SUBJECT ID.	DIMENSION 1	2	3	4
1	1.04	1.32	0.31	-2.32
2	-1.00	0.91	2.02	-1.07
3	-0.94	-0.63	1.91	0.81
4	-2.06	-0.03	0.28	-1.18
5	-0.72	-2.43	-1.00	-0.19
6	-0.93	-0.29	-1.95	-0.32
7	1.82	-0.74	0.29	-0.16
8	0.63	-0.43	-0.20	1.67
9	-0.24	-2.09	0.90	0.78
10	-1.34	-1.51	-0.62	-0.91
11	-1.34	-0.25	-0.01	-0.25
12	-0.49	-1.02	0.02	-1.29
13	0.93	0.04	2.03	-1.14
14	-0.16	0.99	1.04	1.05
15	0.10	-1.45	0.07	0.51
16	0.36	0.27	-0.69	1.04
17	-0.85	0.48	-1.18	0.14
18	-1.03	-0.12	-0.42	-0.65
19	-1.33	-1.27	1.20	-0.64
20	1.84	0.01	-0.77	0.09
21	-0.53	1.26	0.80	-0.57
22	-1.24	0.12	1.49	1.74
23	0.86	-0.93	0.47	1.87
24	-0.11	0.58	-1.20	-0.58
25	0.38	-0.04	0.50	2.71
26	1.98	0.13	-0.26	-0.74
27	0.09	-0.06	-1.09	-0.11
28	-0.20	0.27	-0.18	0.81
29	0.68	-1.62	-0.00	-0.62
30	2.34	-0.64	0.56	0.26
31	0.18	0.44	-0.03	-1.17
32	-0.01	1.15	-0.93	0.70
33	0.85	-0.01	-0.68	0.72
34	0.07	1.85	-1.63	-0.77
35	1.01	-0.29	0.61	-1.23
36	0.81	1.27	1.65	-0.83
37	-0.49	-0.14	0.94	-1.11
38	-0.56	0.71	1.36	1.93
39	-0.36	0.37	-0.91	-0.06
40	-0.21	1.72	-0.86	0.55

TABLE XXXVIII (CONT.)

VARIMAX ROTATIONS OF LOADINGS OF SUBJECTS ON PRINCIPAL VECTORS FOR TUCKER SOLUTIONS - SD12

SUBJECT	DIMENSION			
ID.	1	2	3	4
41	0.29	0.86	-0.32	1.93
42	-0.89	1.59	-0.57	0.35
43	1.13	-0.19	1.31	0.43
44	-0.03	-1.62	-0.97	0.17
45	0.12	-0.97	-1.25	-1.25
46	0.23	-0.22	-1.68	0.33
47	-1.40	0.66	-0.48	0.06
48	-0.66	0.84	0.20	-0.26
49	-0.48	0.01	-1.13	0.55
50	-0.01	-1.93	-0.35	-0.18
51	1.47	0.80	0.31	-0.94
52	2.10	0.12	0.34	-0.69
53	-1.63	0.42	1.70	-0.52
54	0.03	1.66	-0.88	0.58

TABLE XXXIX
KRUSKAL SOLUTIONS OF TUCKER SUBGROUP DATA
CAU9 GROUPS 1,2,3,4; CAU12 GROUPS 1,2

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.02	-0.16	-0.06	-0.01	-0.13	0.02
DISC	-0.08	0.13	0.04	-0.08	-0.08	-0.08
EVID	0.01	-0.16	0.08	-0.01	0.20	0.02
EXPE	0.19	-0.07	-0.02	0.02	0.06	-0.17
EXPL	0.17	0.13	-0.04	0.10	0.08	-0.00
FACT	0.05	0.10	0.14	0.04	-0.07	-0.09
HYPO	-0.06	0.18	-0.09	0.17	-0.08	-0.04
IMAG	0.00	0.04	0.08	0.01	0.03	-0.01
INTE	0.09	-0.06	0.15	0.01	-0.04	0.08
INVE	-0.06	0.00	-0.20	0.06	0.07	0.12
LAW	0.08	0.02	-0.12	-0.06	0.03	0.01
PROO	-0.18	-0.03	-0.02	0.08	-0.11	0.11
PUZZ	0.08	-0.04	-0.10	-0.02	0.06	-0.07
QUES	-0.11	-0.01	0.16	-0.08	-0.02	0.16
THEO	-0.17	-0.06	-0.02	-0.23	0.02	-0.04
CONC	-0.09	-0.11	-0.01	0.03	-0.04	0.09
DISC	-0.00	-0.00	-0.11	0.05	0.00	-0.06
EVID	0.07	0.10	0.09	-0.13	-0.07	-0.09
EXPE	-0.08	-0.03	0.13	-0.01	-0.18	0.00
EXPL	0.07	-0.09	0.12	-0.15	0.08	0.04
FACT	0.04	-0.16	-0.00	-0.12	-0.07	0.07
HYPO	0.01	0.03	0.08	0.06	0.03	0.15
IMAG	0.01	-0.06	-0.09	-0.04	-0.03	0.09
INTE	0.15	-0.01	0.02	-0.04	0.02	-0.12
INVE	0.12	0.00	-0.11	-0.04	0.17	0.06
LAW	-0.02	0.01	-0.03	0.11	-0.07	0.03
PROO	-0.12	0.08	-0.11	0.11	0.10	0.02
PUZZ	-0.10	-0.00	0.00	0.12	0.03	-0.05
QUES	0.04	0.12	-0.04	0.06	-0.11	-0.16
THEO	-0.07	0.13	0.04	-0.01	0.12	-0.07
CONC	0.19	0.08	0.22	0.07	-0.24	0.16
DISC	-0.14	-0.03	0.04	0.02	0.04	-0.31
EVID	-0.27	-0.09	-0.14	-0.16	0.22	-0.20
EXPE	0.02	0.14	-0.29	-0.08	-0.01	0.31
EXPL	-0.03	0.29	-0.06	-0.28	0.09	0.05
FACT	-0.04	-0.27	0.05	-0.27	-0.20	0.06
HYPO	0.34	0.08	-0.10	0.25	-0.14	-0.09
IMAG	-0.15	0.09	0.10	-0.16	-0.03	-0.13
INTE	-0.04	-0.11	-0.14	-0.01	0.25	0.17
INVE	0.12	-0.15	-0.29	-0.06	-0.21	-0.16
LAW	-0.19	0.21	-0.01	0.10	-0.21	-0.06
PROO	-0.15	-0.09	0.26	0.26	0.02	0.23
PUZZ	0.05	0.21	0.11	-0.02	-0.01	0.06
QUES	0.15	-0.24	0.03	0.26	0.16	-0.11
THEO	0.12	-0.12	0.22	0.07	0.27	0.03

TABLE XXXIX (CONT.)
KRUSKAL SOLUTIONS OF TUCKER SUBGROUP DATA
CAU12 GROUPS 3,4; CAS9 GROUPS 1,2,3,4

			DIMENSION			
CONCEPT	1	2	3	1	2	3
CONC	0.08	-0.20	-0.15	-0.08	-0.05	0.16
DISC	-0.17	-0.18	-0.04	-0.12	0.01	-0.14
EVID	-0.06	-0.05	-0.29	-0.15	-0.13	0.04
EXPE	-0.17	0.23	0.13	0.08	0.19	0.02
EXPL	-0.24	0.07	-0.11	0.08	0.11	-0.17
FACT	0.13	0.06	-0.12	0.08	-0.11	-0.04
HYPO	0.34	-0.06	0.03	-0.10	-0.14	-0.14
IMAG	-0.10	-0.02	0.14	-0.01	0.06	-0.00
INTE	0.10	0.24	0.02	0.07	0.03	0.16
INVE	0.11	-0.17	0.16	0.22	-0.05	-0.02
LAW	-0.11	-0.00	0.20	0.05	0.09	0.00
PROO	0.12	0.09	0.23	-0.10	0.10	-0.03
PUZZ	0.18	0.05	-0.14	0.05	-0.07	-0.06
QUES	-0.14	0.30	-0.14	-0.13	0.11	0.10
THEO	-0.08	-0.37	0.08	0.07	-0.14	0.12
CONC	0.03	-0.12	-0.03	-0.04	-0.11	-0.19
DISC	-0.08	-0.03	-0.03	0.16	-0.07	0.01
EVID	0.07	-0.05	0.10	0.02	0.22	-0.01
EXPE	0.03	0.07	0.08	-0.12	-0.03	0.18
EXPL	0.05	0.14	-0.03	0.13	-0.09	0.20
FACT	-0.10	0.03	0.07	-0.08	-0.21	0.07
HYPO	-0.08	0.10	-0.05	0.11	0.15	0.19
IMAG	-0.05	-0.05	-0.02	-0.12	-0.00	-0.02
INTE	0.12	-0.06	-0.01	0.05	-0.22	-0.06
INVE	0.04	-0.03	-0.10	-0.02	0.16	-0.17
LAW	0.07	0.05	-0.01	-0.01	0.00	0.04
PROO	-0.07	0.00	-0.14	-0.20	0.01	-0.08
PUZZ	0.08	0.03	-0.03	0.08	-0.04	-0.14
QUES	-0.08	0.01	0.11	-0.19	0.13	0.08
THEO	-0.01	-0.10	0.09	0.22	0.08	-0.11
CONC	0.00	-0.20	0.07	0.07	-0.11	-0.03
DISC	0.09	-0.06	-0.15	-0.06	0.03	-0.11
EVID	0.04	0.25	0.04	0.01	-0.11	0.08
EXPE	-0.09	-0.10	0.21	0.14	0.05	-0.00
EXPL	-0.10	0.02	-0.21	0.08	0.01	0.12
FACT	-0.24	-0.09	0.03	0.05	-0.01	-0.11
HYPO	0.23	-0.13	0.06	-0.01	-0.10	-0.07
IMAG	0.04	-0.04	-0.09	0.02	-0.04	0.04
INTE	0.09	0.06	0.13	-0.03	0.14	0.06
INVE	-0.06	0.20	-0.12	-0.06	0.02	0.11
LAW	0.12	0.02	0.11	0.02	0.05	0.02
PROO	-0.07	-0.21	-0.11	-0.14	-0.01	0.00
PUZZ	-0.15	0.06	0.03	0.05	0.05	-0.04
QUES	0.24	0.12	-0.09	-0.08	-0.07	-0.04
THEO	-0.14	0.07	0.10	-0.08	0.10	-0.04

TABLE XXXIX (CONT.)
KRUSKAL SOLUTIONS OF TUCKER SUBGROUP DATA
CAS12 GROUPS 1,2,3,4; SJ9 GROUPS 1,2

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	0.20	-0.18	0.06	-0.13	-0.08	0.08
DISC	0.04	0.10	-0.23	0.02	0.16	0.01
EVID	-0.20	0.05	0.16	-0.10	-0.17	0.02
EXPE	0.15	0.22	0.11	0.09	0.01	0.21
EXPL	-0.25	0.12	-0.06	-0.14	0.06	0.11
FACT	0.14	-0.12	-0.15	0.11	-0.16	0.08
HYPO	-0.21	-0.06	-0.23	0.18	-0.01	-0.00
IMAG	0.01	0.11	-0.02	0.01	0.04	0.07
INTE	0.05	0.05	0.21	0.08	0.05	-0.16
INVE	-0.21	-0.16	0.09	0.08	-0.10	-0.19
LAW	-0.02	-0.21	-0.02	0.10	0.09	0.06
PROO	-0.01	0.23	-0.03	-0.16	0.09	-0.05
PUZZ	-0.01	-0.06	-0.10	0.02	-0.06	-0.01
QUES	0.27	0.05	-0.03	-0.01	0.19	-0.11
THEO	0.04	-0.14	0.23	-0.15	-0.09	-0.12
CONC	0.07	-0.08	0.02	0.19	-0.02	-0.12
DISC	-0.00	-0.04	-0.06	-0.07	0.23	-0.13
EVID	-0.01	0.14	0.09	-0.21	0.13	0.02
EXPE	-0.03	-0.17	0.06	0.12	-0.25	0.12
EXPL	-0.08	0.01	0.14	-0.20	-0.19	0.04
FACT	-0.06	-0.09	-0.12	0.05	-0.18	-0.18
HYPO	-0.15	0.04	-0.02	-0.18	0.08	0.26
IMAG	0.02	0.05	0.02	0.09	0.00	0.15
INTE	0.07	-0.10	-0.07	0.07	0.21	0.13
INVE	0.14	-0.03	0.11	-0.23	-0.13	-0.04
LAW	-0.11	-0.08	0.05	0.07	-0.09	0.11
PROO	-0.01	0.11	-0.14	0.14	0.08	0.20
PUZZ	-0.08	0.11	0.00	0.11	-0.14	-0.14
QUES	0.10	0.00	-0.14	0.17	0.26	-0.13
THEO	0.13	0.11	0.07	-0.11	0.00	-0.27
CONC	-0.03	-0.20	0.16	-0.09	0.04	0.05
DISC	0.03	-0.18	-0.19	0.04	-0.06	-0.08
EVID	-0.09	0.02	-0.27	0.08	-0.05	0.10
EXPE	-0.20	-0.21	0.00	-0.04	0.10	-0.03
EXPL	-0.13	0.24	-0.14	0.11	0.04	0.00
FACT	0.21	-0.23	0.05	-0.07	0.02	-0.08
HYPO	0.11	-0.01	0.22	-0.03	-0.11	-0.02
IMAG	-0.06	-0.08	-0.03	0.04	0.06	-0.04
INTE	0.27	0.00	0.03	-0.03	-0.05	0.07
INVE	0.17	0.22	-0.09	0.06	-0.07	0.01
LAW	-0.24	0.04	0.02	-0.10	-0.04	0.01
PROO	0.04	0.18	0.20	0.06	0.03	-0.07
PUZZ	-0.05	0.12	0.02	-0.07	-0.01	-0.04
QUES	0.14	-0.01	-0.16	0.03	0.04	0.09
THEO	-0.16	0.09	0.19	-0.00	0.08	0.05

TABLE XXXIX (CONT.)
KRUSKAL SOLUTIONS OF TUCKER SUBGROUP DATA
SJ9 GROUPS 3,4; SJ12 GROUPS 1,2,3,4

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	0.05	0.00	-0.15	0.16	-0.01	-0.14
DISC	0.15	-0.08	-0.04	-0.13	-0.15	-0.01
EVID	-0.17	-0.03	-0.05	0.25	0.03	0.05
EXPE	0.10	-0.13	0.11	0.02	-0.18	-0.13
EXPL	-0.08	-0.17	-0.04	-0.01	-0.16	0.16
FACT	-0.08	-0.10	0.12	-0.21	0.00	-0.13
HYPO	-0.02	0.06	-0.15	0.01	0.22	0.02
IMAG	0.06	-0.00	0.02	-0.16	0.01	-0.03
INTE	0.03	-0.02	0.17	0.09	0.02	0.20
INVE	-0.11	0.13	-0.07	-0.01	0.04	-0.23
LAW	0.02	0.13	0.01	0.00	0.17	-0.05
PROO	0.18	0.12	-0.02	-0.19	0.05	0.10
PUZZ	-0.03	-0.10	-0.11	0.16	0.08	-0.05
QUES	0.04	0.13	0.11	-0.10	0.06	0.18
THEO	-0.15	0.06	0.09	0.12	-0.19	0.04
CONC	0.14	-0.19	-0.03	0.06	0.12	0.02
DISC	-0.18	-0.04	0.05	-0.12	-0.04	-0.10
EVID	-0.02	0.25	-0.02	0.18	0.09	-0.08
EXPE	-0.02	-0.20	-0.05	-0.10	0.12	-0.11
EXPL	0.12	-0.06	0.13	0.19	-0.00	0.05
FACT	-0.16	-0.03	-0.13	-0.08	0.13	0.09
HYPO	0.14	-0.00	-0.08	0.08	-0.07	0.12
IMAG	-0.04	-0.01	0.14	-0.03	0.08	0.07
INTE	-0.06	0.08	-0.06	-0.16	-0.00	0.03
INVE	0.01	0.05	-0.22	-0.01	-0.05	0.19
LAW	-0.08	-0.16	0.12	0.01	-0.11	-0.13
PROO	0.20	0.14	0.04	-0.13	-0.14	0.05
PUZZ	0.03	-0.03	-0.10	0.04	-0.07	-0.08
QUES	0.05	0.08	0.12	0.02	0.07	-0.15
THEO	-0.12	0.13	0.09	0.05	-0.13	0.03
CONC	0.08	-0.09	0.00	0.11	-0.09	-0.09
DISC	-0.07	-0.07	0.02	-0.14	0.08	-0.01
EVID	-0.02	0.11	-0.04	-0.05	0.05	-0.17
EXPE	-0.08	0.03	0.09	-0.02	-0.19	0.03
EXPL	0.05	0.01	0.11	-0.12	-0.09	-0.09
FACT	-0.08	-0.03	-0.07	-0.04	-0.05	0.15
HYPO	0.00	-0.10	-0.01	0.11	0.02	0.11
IMAG	-0.00	0.00	-0.01	0.06	-0.01	-0.12
INTE	0.04	0.10	0.01	-0.04	0.10	0.12
INVE	0.11	0.06	-0.01	0.11	0.17	0.01
LAW	-0.01	-0.03	0.08	0.10	-0.06	0.07
PROO	0.06	-0.04	-0.10	0.06	0.09	-0.10
PUZZ	0.01	0.01	0.03	0.05	-0.07	-0.01
QUES	0.00	0.01	-0.09	-0.04	0.10	0.03
THEO	-0.10	0.05	-0.03	-0.14	-0.05	0.06

TABLE XXXIX (CONT.)
KRUSKAL SOLUTIONS OF TUCKER SUBGROUP DATA
SD9 GROUPS 1,2,3,4; SD12 GROUPS 1,2

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	0.19	-0.08	0.05	0.18	-0.21	0.27
DISC	0.21	0.02	-0.16	0.15	-0.17	-0.10
EVID	-0.18	0.09	0.15	-0.18	-0.04	0.26
EXPE	-0.00	-0.18	-0.10	-0.08	-0.15	-0.20
EXPL	0.03	0.10	-0.22	-0.13	0.08	-0.25
FACT	0.10	0.12	0.14	-0.05	0.29	0.17
HYPO	0.03	0.05	0.22	0.18	0.28	-0.03
IMAG	-0.15	0.07	-0.18	-0.05	0.29	-0.17
INTE	-0.00	-0.15	-0.17	0.04	-0.34	0.03
INVE	0.08	0.21	0.01	0.16	0.06	0.21
LAW	-0.07	-0.18	0.12	-0.34	0.01	-0.09
PROO	-0.25	-0.07	0.01	0.22	-0.03	-0.32
PUZZ	0.17	0.01	0.08	0.27	0.03	-0.01
QUES	-0.12	0.20	-0.01	-0.12	0.11	0.18
THEO	-0.02	-0.20	0.05	-0.24	-0.21	0.06
CONC	-0.24	-0.11	-0.02	-0.12	-0.03	0.36
DISC	0.04	0.05	0.19	-0.19	0.05	-0.33
EVID	0.11	-0.19	-0.12	-0.10	-0.30	-0.27
EXPE	-0.05	-0.26	0.03	0.24	0.02	-0.32
EXPL	0.24	-0.12	0.04	0.38	-0.10	-0.13
FACT	-0.21	0.18	0.12	-0.42	0.02	0.02
HYPO	0.12	0.00	-0.11	-0.30	0.24	-0.18
IMAG	-0.18	0.12	-0.12	0.13	0.34	-0.13
INTE	0.02	-0.09	0.21	0.13	-0.41	0.10
INVE	-0.03	-0.09	-0.06	-0.15	0.38	0.17
LAW	0.02	0.20	-0.01	-0.19	-0.29	0.14
PROO	0.15	0.19	-0.18	0.17	0.23	0.08
PUZZ	-0.05	0.01	-0.20	0.00	-0.15	-0.05
QUES	-0.09	0.02	0.12	0.13	0.09	0.35
THEO	0.15	0.11	0.10	0.28	-0.08	0.18
CONC	0.08	-0.08	0.05	0.13	0.03	0.10
DISC	0.21	-0.02	0.19	0.07	0.11	-0.06
EVID	0.08	0.16	0.01	-0.10	-0.05	0.08
EXPE	-0.06	-0.05	0.00	-0.08	0.11	-0.04
EXPL	-0.01	-0.21	0.21	0.01	0.05	-0.10
FACT	-0.14	0.01	-0.23	-0.03	0.04	0.13
HYPO	0.19	0.02	-0.06	0.08	0.00	0.02
IMAG	-0.07	0.06	0.19	0.03	-0.05	-0.09
INTE	-0.04	-0.19	-0.03	-0.04	-0.01	-0.01
INVE	0.10	-0.16	-0.11	0.12	-0.07	-0.03
LAW	0.12	0.10	-0.26	-0.07	-0.04	-0.13
PROO	-0.30	-0.00	-0.02	-0.02	-0.14	0.01
PUZZ	-0.11	0.03	0.01	0.04	-0.08	0.10
QUES	-0.05	0.19	-0.05	-0.02	0.11	0.06
THEO	-0.01	0.14	0.11	-0.12	-0.01	-0.03

TABLE XXXIX (CONT.)
KRUSKAL SOLUTIONS OF TUCKER SUBGROUP DATA
SD12 GROUPS 3,4

			DIMENSION			
CONCEPT	1	2	3	1	2	3
CONC	-0.07	-0.20	0.07	0.22	0.12	-0.08
DISC	0.04	-0.20	-0.08	-0.24	0.10	-0.16
EVID	0.01	0.15	0.15	-0.03	-0.02	-0.03
EXPE	0.10	-0.06	0.11	0.02	0.27	-0.03
EXPL	-0.11	0.03	0.08	-0.18	-0.06	0.25
FACT	0.15	0.03	-0.05	-0.01	-0.15	-0.26
HYPO	0.18	-0.06	-0.06	0.03	0.09	-0.26
IMAG	-0.17	0.12	-0.07	0.02	-0.33	0.03
INTE	0.08	-0.08	0.15	0.11	-0.20	0.24
INVE	-0.12	-0.09	-0.08	0.31	-0.01	0.06
LAW	0.03	0.19	-0.03	-0.26	-0.19	-0.02
PROO	-0.07	-0.00	-0.20	0.04	0.00	0.19
PUZZ	0.08	0.04	-0.13	0.16	-0.08	-0.18
QUES	-0.14	-0.02	0.08	-0.22	0.21	0.04
THEO	0.01	0.13	0.05	0.04	0.25	0.22

TABLE XL

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAU9

SUBJECT ID.	DIMENSION 1	2	3
1	0.33	0.16	0.27
2	0.18	0.45	0.49
3	0.53	0.22	0.26
4	0.15	0.26	0.18
5	0.29	0.36	0.23
6	0.24	0.38	0.49
7	0.22	0.40	0.42
8	0.30	0.26	0.66
9	0.18	0.42	0.48
10	0.47	0.33	0.23
11	0.45	0.29	0.33
12	0.43	0.15	0.45
13	0.35	0.50	0.26
14	0.33	0.25	0.27
15	0.39	0.35	0.33
16	0.27	0.33	0.17
17	0.18	0.61	0.26
18	0.26	0.22	0.30
19	0.35	0.31	0.32
20	0.18	0.36	0.16
21	0.23	0.38	0.22
22	0.33	0.17	0.25
23	0.20	0.21	0.30
24	0.21	0.39	0.24
25	0.47	0.24	0.25
26	0.36	0.25	0.24
27	0.19	0.42	0.31
28	0.27	0.22	0.28
29	0.38	0.34	0.28
30	0.28	0.36	0.24
31	0.38	0.31	0.12
32	0.28	0.40	0.37
33	0.26	0.36	0.47
34	0.40	0.34	0.37
35	0.47	0.37	0.20
36	0.46	0.35	0.31
37	0.14	0.36	0.51
38	0.47	0.26	0.31
39	0.23	0.27	0.20
40	0.37	0.41	0.12

TABLE XI (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAU9

SUBJECT	DIMENSION		
ID.	1	2	3
41	0.49	0.31	0.22
42	0.48	0.41	0.38
43	0.22	0.23	0.57
44	0.39	0.49	0.38
45	0.28	0.31	0.37
46	0.41	0.29	0.39
47	0.24	0.20	0.25
48	0.24	0.37	0.35
49	0.27	0.14	0.67
50	0.42	0.15	0.38
51	0.04	0.28	0.19
52	0.45	0.35	0.36
53	0.31	0.29	0.56
54	0.18	0.66	0.17
55	0.35	0.28	0.40
56	0.37	0.38	0.23
57	0.36	0.46	0.33
58	0.46	0.29	0.35
59	0.34	0.39	0.25
60	0.36	0.42	0.23
61	0.47	0.40	0.32
62	0.47	0.37	0.45
63	0.22	0.30	0.56
64	0.51	0.32	0.32
65	0.44	0.36	0.28
66	0.40	0.38	0.23
67	0.35	0.21	0.33
68	0.41	0.34	0.24
69	0.39	0.35	0.19
70	0.32	0.32	0.26
71	0.22	0.21	0.45
72	0.29	0.20	0.22
73	0.34	0.39	0.16
74	0.27	0.37	0.27
75	0.39	0.38	0.31
76	0.33	0.24	0.20
77	0.34	0.34	0.40
78	0.22	0.33	0.32

TABLE XLI

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAU12

SUBJECT ID.	DIMENSION 1	2	3
1	0.27	0.25	0.30
2	0.30	0.30	0.34
3	0.28	0.24	0.24
4	0.41	0.38	0.22
5	0.22	0.16	0.29
6	0.24	0.37	0.28
7	0.40	0.25	0.31
8	0.28	0.35	0.49
9	0.43	0.33	0.32
10	0.29	0.28	0.26
11	0.55	0.41	0.15
12	0.29	0.55	0.23
13	0.35	0.34	0.42
14	0.33	0.16	0.44
15	0.26	0.30	0.30
16	0.29	0.38	0.20
17	0.48	0.43	0.30
18	0.43	0.39	0.25
19	0.10	0.17	0.68
20	0.32	0.30	0.34
21	0.23	0.31	0.14
22	0.39	0.36	0.31
23	0.35	0.27	0.17
24	0.56	0.26	0.37
25	0.38	0.30	0.36
26	0.43	0.42	0.24
27	0.54	0.31	0.15
28	0.30	0.23	0.27
29	0.38	0.28	0.40
30	0.38	0.13	0.26
31	0.38	0.46	0.19
32	0.20	0.25	0.25
33	0.29	0.19	0.18
34	0.49	0.27	0.36
35	0.23	0.39	0.13
36	0.41	0.35	0.30
37	0.19	0.25	0.14
38	0.41	0.19	0.12
39	0.57	0.28	0.25
40	0.39	0.42	0.33

TABLE XLI (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAU12

SUBJECT ID.	DIMENSION 1	2	3
41	0.39	0.36	0.20
42	0.42	0.36	0.26
43	0.34	0.20	0.30
44	0.35	0.42	0.22
45	0.33	0.32	0.39
46	0.45	0.29	0.34
47	0.21	0.52	0.34
48	0.30	0.45	0.30
49	0.54	0.37	0.28
50	0.27	0.28	0.41
51	0.35	0.38	0.15
52	0.33	0.25	0.32
53	0.41	0.26	0.25
54	0.48	0.34	0.19

TABLE XLII

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAS9

SUBJECT ID.	DIMENSION 1	2	3
1	0.27	0.34	0.16
2	0.49	0.19	0.44
3	0.27	0.53	0.21
4	0.17	0.16	0.26
5	0.23	0.30	0.36
6	0.49	0.25	0.36
7	0.43	0.22	0.39
8	0.67	0.29	0.26
9	0.50	0.17	0.41
10	0.24	0.48	0.33
11	0.34	0.45	0.28
12	0.48	0.41	0.14
13	0.27	0.35	0.49
14	0.28	0.32	0.25
15	0.34	0.38	0.35
16	0.17	0.27	0.33
17	0.27	0.18	0.61
18	0.31	0.26	0.23
19	0.32	0.35	0.31
20	0.17	0.18	0.35
21	0.22	0.24	0.37
22	0.25	0.33	0.17
23	0.29	0.21	0.21
24	0.24	0.21	0.39
25	0.27	0.47	0.23
26	0.25	0.36	0.24
27	0.31	0.19	0.42
28	0.28	0.27	0.22
29	0.29	0.37	0.33
30	0.25	0.28	0.36
31	0.12	0.40	0.30
32	0.38	0.27	0.40
33	0.47	0.27	0.35
34	0.38	0.40	0.34
35	0.21	0.48	0.36
36	0.32	0.45	0.35
37	0.51	0.14	0.36
38	0.33	0.46	0.25
39	0.20	0.24	0.26
40	0.12	0.38	0.42

TABLE XLII (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAS9

SUBJECT		DIMENSION	
ID.	1	2	3
41	0.23	0.50	0.31
42	0.38	0.49	0.40
43	0.57	0.21	0.23
44	0.40	0.38	0.49
45	0.37	0.28	0.31
46	0.40	0.38	0.30
47	0.25	0.25	0.19
48	0.36	0.23	0.36
49	0.68	0.26	0.13
50	0.40	0.41	0.14
51	0.19	0.04	0.28
52	0.37	0.44	0.35
53	0.56	0.30	0.29
54	0.18	0.19	0.63
55	0.41	0.34	0.27
56	0.23	0.37	0.37
57	0.34	0.37	0.44
58	0.36	0.45	0.29
59	0.25	0.33	0.39
60	0.23	0.37	0.41
61	0.33	0.47	0.39
62	0.45	0.46	0.37
63	0.57	0.20	0.30
64	0.34	0.51	0.31
65	0.28	0.44	0.35
66	0.23	0.41	0.37
67	0.34	0.35	0.21
68	0.24	0.41	0.33
69	0.20	0.39	0.34
70	0.26	0.33	0.32
71	0.44	0.21	0.21
72	0.22	0.29	0.20
73	0.17	0.34	0.39
74	0.27	0.27	0.38
75	0.32	0.39	0.37
76	0.21	0.33	0.23
77	0.40	0.33	0.35
78	0.33	0.21	0.33

TABLE XLIII

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAS12

SUBJECT ID.	DIMENSION 1	2	3
1	0.28	0.24	0.30
2	0.31	0.29	0.34
3	0.27	0.24	0.25
4	0.42	0.37	0.21
5	0.21	0.17	0.30
6	0.25	0.37	0.28
7	0.42	0.23	0.30
8	0.29	0.35	0.48
9	0.44	0.32	0.31
10	0.30	0.27	0.26
11	0.56	0.40	0.13
12	0.29	0.54	0.22
13	0.36	0.34	0.39
14	0.32	0.16	0.45
15	0.27	0.30	0.30
16	0.29	0.38	0.20
17	0.49	0.42	0.31
18	0.42	0.40	0.25
19	0.10	0.17	0.68
20	0.31	0.31	0.34
21	0.25	0.29	0.13
22	0.38	0.36	0.34
23	0.34	0.29	0.16
24	0.55	0.26	0.38
25	0.39	0.29	0.37
26	0.44	0.40	0.25
27	0.56	0.28	0.15
28	0.31	0.23	0.27
29	0.38	0.28	0.41
30	0.36	0.13	0.28
31	0.39	0.45	0.20
32	0.21	0.26	0.23
33	0.28	0.20	0.18
34	0.51	0.25	0.35
35	0.24	0.38	0.13
36	0.43	0.33	0.30
37	0.17	0.24	0.17
38	0.40	0.20	0.13
39	0.57	0.28	0.25
40	0.41	0.40	0.34

TABLE XLIII (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - CAS12

SUBJECT ID.	DIMENSION 1	2	3
41	0.40	0.36	0.20
42	0.41	0.37	0.26
43	0.34	0.19	0.30
44	0.35	0.40	0.23
45	0.32	0.31	0.40
46	0.47	0.28	0.33
47	0.22	0.53	0.33
48	0.31	0.42	0.32
49	0.54	0.36	0.27
50	0.26	0.28	0.42
51	0.34	0.39	0.15
52	0.33	0.25	0.32
53	0.42	0.25	0.26
54	0.49	0.34	0.19

TABLE XLIV

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SJ9

SUBJECT ID.	DIMENSION 1	2	3
1	0.12	0.24	0.17
2	0.52	0.47	0.23
3	0.51	0.46	0.22
4	0.37	0.33	0.27
5	0.20	0.37	0.21
6	0.56	0.38	0.21
7	0.56	0.39	0.28
8	0.67	0.17	0.18
9	0.60	0.40	0.17
10	0.51	0.26	0.26
11	0.25	0.33	0.18
12	0.46	0.47	0.17
13	0.35	0.52	0.29
14	0.30	0.27	0.23
15	0.62	0.38	0.10
16	0.19	0.32	0.19
17	0.51	0.31	0.30
18	0.37	0.21	0.28
19	0.47	0.16	0.28
20	0.20	0.28	0.24
21	0.35	0.20	0.42
22	0.25	0.30	0.26
23	0.41	0.37	0.09
24	0.34	0.17	0.19
25	0.26	0.42	0.21
26	0.43	0.22	0.24
27	0.37	0.13	0.45
28	0.32	0.31	0.25
29	0.42	0.30	0.22
30	0.43	0.38	0.29
31	0.66	0.30	0.20
32	0.28	0.44	0.34
33	0.67	0.26	0.26
34	0.42	0.39	0.37
35	0.45	0.32	0.33
36	0.46	0.38	0.21
37	0.43	0.27	0.25
38	0.32	0.24	0.52
39	0.26	0.26	0.40
40	0.46	0.43	0.21

TABLE XLIV (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SJ9

SUBJECT ID.	DIMENSION 1	2	3
41	0.38	0.24	0.19
42	0.45	0.33	0.32
43	0.70	0.17	0.21
44	0.31	0.43	0.16
45	0.38	0.38	0.31
46	0.33	0.32	0.17
47	0.08	0.02	0.03
48	0.50	0.24	0.37
49	0.61	0.26	0.38
50	0.46	0.26	-0.09
51	0.30	0.26	0.24
52	0.48	0.22	0.25
53	0.34	0.17	0.31
54	0.35	0.39	0.36
55	0.51	0.26	0.33
56	0.13	0.37	0.21
57	0.66	0.29	0.21
58	0.37	0.18	0.28
59	0.37	0.40	0.45
60	0.42	0.25	0.18
61	0.28	0.42	0.24
62	0.19	0.46	0.31
63	0.68	0.20	0.29
64	0.57	0.29	0.21
65	0.12	0.32	0.38
66	0.42	0.22	0.39
67	0.51	0.18	0.16
68	0.43	0.33	0.36
69	0.33	0.17	0.05
70	0.34	0.23	0.09
71	0.48	0.19	0.47
72	0.45	0.15	0.24
73	0.24	0.14	0.42
74	0.37	0.23	0.36
75	0.49	0.38	0.16
76	0.50	0.10	0.41
77	0.51	0.38	0.31
78	0.57	0.37	0.13

TABLE XLV

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SJ12

SUBJECT ID.	DIMENSION		
	1	2	3
1	0.24	0.28	0.42
2	0.17	0.31	0.41
3	0.26	0.17	0.20
4	0.51	0.34	0.16
5	0.28	0.54	0.07
6	0.41	0.25	0.35
7	0.30	0.31	0.19
8	0.32	0.27	0.48
9	0.35	0.32	0.18
10	0.43	0.22	0.15
11	0.46	0.32	0.23
12	0.36	0.28	0.42
13	0.41	0.38	0.22
14	0.44	0.29	0.15
15	0.25	0.26	0.42
16	0.49	0.32	0.01
17	0.56	0.28	0.20
18	0.26	0.21	0.27
19	0.17	0.39	0.52
20	0.44	0.19	0.28
21	0.54	0.35	0.17
22	0.27	0.45	0.36
23	0.38	0.32	0.25
24	0.37	0.35	0.14
25	0.41	0.44	0.21
26	0.29	0.31	0.31
27	0.44	0.29	0.08
28	0.22	0.20	0.36
29	0.33	0.41	0.18
30	0.41	0.18	0.28
31	0.61	0.32	0.14
32	0.07	0.20	0.42
33	0.36	0.38	0.15
34	0.61	0.35	0.16
35	0.50	0.17	0.19
36	0.12	0.39	0.20
37	0.22	0.24	0.29
38	0.22	0.27	0.40
39	0.31	0.26	0.14
40	0.48	0.23	0.19

TABLE XLV (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SJ12

SUBJECT ID.	DIMENSION 1	2	3
41	0.46	0.26	0.21
42	0.34	0.31	0.25
43	0.26	0.33	0.23
44	0.29	0.43	0.51
45	0.35	0.49	0.23
46	0.05	0.15	0.22
47	0.44	0.26	0.14
48	0.32	0.23	0.13
49	0.58	0.27	0.11
50	0.36	0.24	0.25
51	0.40	0.29	0.22
52	0.32	0.21	0.23
53	0.27	0.27	0.24
54	0.51	0.25	0.30

TABLE XLVI

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SD9

SUBJECT	DIMENSION		
ID.	1	2	3
1	0.00	0.03	0.18
2	0.40	0.22	0.05
3	0.13	0.59	0.28
4	-0.03	0.19	0.07
5	0.32	0.09	0.08
6	0.41	0.16	0.01
7	0.18	0.22	0.43
8	0.57	0.23	0.10
9	-0.03	-0.01	0.08
10	0.07	0.08	0.16
11	0.44	0.14	0.43
12	0.14	0.66	0.21
13	0.22	0.48	0.14
14	0.11	0.08	0.78
15	0.02	0.56	0.43
16	0.08	0.14	0.04
17	0.39	0.21	0.49
18	0.04	0.65	0.22
19	0.04	0.16	0.20
20	0.10	0.12	0.12
21	0.34	0.30	0.12
22	0.08	0.31	-0.00
23	0.30	0.38	0.40
24	0.52	-0.00	0.30
25	0.38	0.16	0.05
26	0.76	0.06	0.00
27	0.21	0.57	0.27
28	0.27	0.25	0.32
29	0.21	0.25	0.44
30	0.38	0.18	0.13
31	-0.01	0.27	0.17
32	0.11	0.04	-0.01
33	0.35	0.32	0.10
34	0.12	0.41	0.02
35	0.37	0.41	-0.02
36	0.11	0.19	0.01
37	0.29	0.23	0.38
38	0.09	0.48	0.22
39	0.17	-0.07	0.26
40	0.13	0.12	0.04

TABLE XLVI (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SD9

SUBJECT ID.	DIMENSION 1	2	3
41	0.46	0.06	0.09
42	0.30	0.22	0.28
43	0.18	0.11	0.23
44	0.31	0.31	-0.06
45	0.71	0.04	0.25
46	0.33	0.20	0.20
47	0.11	0.07	0.04
48	0.13	0.27	0.05
49	0.29	0.68	0.02
50	0.36	0.12	0.12
51	0.06	-0.07	0.79
52	0.40	0.45	0.21
53	0.44	0.18	0.21
54	0.26	0.03	0.42
55	0.73	-0.00	0.11
56	0.34	0.00	0.03
57	0.31	0.17	0.14
58	0.09	0.22	0.11
59	0.69	0.02	0.21
60	0.06	0.22	0.05
61	0.09	0.12	0.46
62	0.11	0.19	0.27
63	-0.01	0.44	0.34
64	0.39	0.16	0.56
65	0.50	0.14	0.14
66	0.57	0.37	-0.09
67	0.01	0.69	-0.03
68	0.25	0.42	0.06
69	0.14	0.08	0.21
70	0.41	0.15	-0.02
71	0.37	0.42	0.45
72	0.01	0.49	0.00
73	0.44	0.42	0.18
74	0.06	0.10	0.57
75	0.14	0.52	0.10
76	0.54	0.41	0.17
77	0.22	0.02	0.14
78	0.13	0.26	-0.05

TABLE XLVII

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SD12

SUBJECT ID.	DIMENSION 1	2	3
1	0.00	0.26	0.39
2	0.03	0.17	0.13
3	0.04	0.01	0.07
4	0.41	0.31	0.04
5	0.13	0.37	0.08
6	0.35	0.64	-0.04
7	0.14	0.03	0.06
8	0.38	0.20	0.09
9	0.14	0.18	0.06
10	0.10	0.71	0.04
11	0.52	0.35	0.07
12	0.27	0.30	0.33
13	0.10	0.07	0.19
14	0.29	0.03	0.08
15	0.11	0.11	0.40
16	0.24	0.39	0.31
17	0.46	0.46	0.09
18	0.14	0.30	0.17
19	0.24	0.13	0.07
20	0.08	0.17	0.65
21	0.54	-0.03	0.46
22	0.73	-0.04	0.05
23	0.24	0.19	0.13
24	0.38	0.35	0.17
25	0.50	0.01	0.05
26	0.05	-0.02	0.85
27	0.30	0.08	0.07
28	-0.01	0.43	0.09
29	0.01	0.18	0.08
30	0.03	0.06	0.21
31	0.15	0.14	0.48
32	0.28	0.27	0.34
33	0.31	0.08	0.23
34	0.40	0.35	0.46
35	0.07	0.19	0.12
36	0.29	0.08	0.27
37	0.12	0.32	0.26
38	0.71	-0.05	0.07
39	0.49	0.34	0.19
40	0.61	0.05	0.13

TABLE XLVII (CONT.)

LOADINGS OF SUBJECTS ON DIMENSIONS FOR CARROLL SOLUTIONS OF FULL GROUPS - SD12

SUBJECT ID.	DIMENSION 1	2	3
41	0.68	0.06	0.18
42	0.60	0.05	0.04
43	0.03	0.15	0.25
44	0.28	0.32	0.25
45	-0.01	0.70	0.32
46	0.23	0.56	0.10
47	0.25	0.41	0.13
48	0.29	-0.00	0.14
49	0.39	0.40	0.16
50	0.13	0.43	0.26
51	0.13	0.03	0.25
52	0.11	0.04	0.44
53	0.37	0.08	0.06
54	0.55	0.13	0.27

TABLE X[illegible]VIII
KRUSKAL SOLUTIONS OF CARROLL SUBGROUPS
CAU9 GRPS 1,2,3; CAU12 GRPS 1,2,3

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	0.11	-0.17	-0.14	0.05	-0.14	-0.02
DISC	-0.12	0.19	0.09	0.02	0.11	-0.06
EVID	0.04	-0.02	-0.22	0.15	-0.01	-0.13
EXPE	-0.25	-0.06	0.10	-0.01	-0.11	-0.15
EXPL	-0.19	0.07	-0.16	-0.06	0.02	-0.16
FACT	0.02	-0.16	0.18	-0.05	-0.16	0.09
HYPO	0.19	0.12	-0.12	-0.17	-0.09	-0.02
IMAG	-0.03	0.05	0.11	0.02	0.11	-0.05
INTE	0.13	0.17	0.16	0.15	-0.04	0.03
INVE	0.20	-0.06	0.11	0.02	0.06	0.17
LAW	-0.02	0.19	0.04	-0.11	-0.01	0.10
PROO	-0.17	-0.15	-0.05	-0.08	0.17	0.08
PUZZ	0.16	-0.11	0.05	0.07	-0.10	0.12
QUES	-0.00	0.14	-0.19	-0.16	0.08	-0.05
THEO	-0.08	-0.21	0.03	0.15	0.11	0.05
CONC	-0.09	0.08	0.09	0.19	-0.02	-0.09
DISC	-0.07	-0.13	-0.10	-0.19	0.06	-0.12
EVID	-0.12	0.11	-0.08	0.22	-0.11	0.15
EXPE	0.02	-0.03	-0.18	0.05	0.25	-0.06
EXPL	0.11	0.10	-0.12	-0.12	0.20	0.02
FACT	0.08	-0.18	-0.01	0.04	0.08	-0.25
HYPO	-0.01	-0.15	0.05	0.03	0.17	0.23
IMAG	-0.13	0.04	0.05	-0.13	-0.05	0.14
INTE	0.16	-0.03	-0.06	0.17	0.10	0.10
INVE	0.16	-0.03	0.12	-0.01	-0.23	0.10
LAW	0.05	0.17	0.02	-0.05	-0.15	0.12
PROO	-0.12	-0.10	0.10	-0.23	0.01	0.14
PUZZ	0.08	0.13	0.08	0.13	0.02	-0.15
QUES	-0.14	0.03	-0.13	0.05	-0.22	-0.15
THEO	0.02	-0.01	0.17	-0.15	-0.13	-0.17
CONC	0.02	0.14	0.16	0.04	0.06	0.25
DISC	-0.23	-0.06	-0.11	0.08	0.16	-0.22
EVID	-0.06	0.41	0.01	-0.21	-0.08	-0.15
EXPE	-0.27	0.16	0.17	-0.21	-0.14	0.16
EXPL	-0.18	0.12	-0.29	-0.18	0.08	0.11
FACT	-0.27	-0.21	0.10	0.22	-0.08	0.16
HYPO	0.07	-0.07	-0.38	0.18	-0.00	-0.14
IMAG	0.11	0.15	-0.00	0.06	-0.05	0.16
INTE	0.17	-0.10	0.31	-0.01	-0.15	-0.25
INVE	0.16	-0.32	-0.02	0.17	-0.18	-0.05
LAW	-0.07	-0.30	-0.07	-0.03	-0.24	0.04
PROO	0.32	-0.10	-0.10	-0.10	0.19	-0.12
PUZZ	0.23	0.11	0.05	-0.16	0.03	-0.07
QUES	0.08	0.15	-0.15	0.19	0.12	0.04
THEO	-0.07	-0.08	0.34	-0.02	0.26	0.08

TABLE XLVIII (CONT.)
KRUSKAL SOLUTIONS OF CARROLL SUBGROUPS
CAS9 GRPS 1,2,3; CAS12 GRPS 1,2,3

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.02	-0.21	0.06	-0.06	-0.14	-0.19
DISC	-0.03	-0.01	-0.25	-0.03	0.13	0.18
EVID	0.21	0.05	-0.21	0.15	-0.04	-0.24
EXPE	0.10	-0.21	-0.17	-0.15	-0.20	0.09
EXPL	0.28	-0.07	0.02	0.07	-0.22	-0.07
FACT	0.06	-0.15	0.24	-0.26	0.01	-0.06
HYPO	-0.21	0.08	-0.06	0.27	-0.03	-0.02
IMAG	0.02	-0.18	0.14	-0.11	0.12	0.13
INTE	0.10	0.11	0.20	0.20	0.13	0.05
INVE	-0.06	0.26	0.12	0.02	0.17	-0.17
LAW	-0.16	0.03	0.20	-0.05	0.18	0.12
PROO	-0.30	0.10	-0.06	0.10	-0.15	0.21
PUZZ	0.20	0.20	0.03	0.00	0.18	-0.11
QUES	-0.19	-0.20	-0.10	0.08	-0.14	0.16
THEO	0.01	0.20	-0.15	-0.24	-0.01	-0.07
CONC	0.07	-0.02	0.12	-0.13	-0.04	0.01
DISC	0.07	-0.04	-0.06	0.00	0.01	-0.16
EVID	-0.07	-0.14	0.08	0.06	-0.15	-0.13
EXPE	-0.06	0.12	0.09	-0.05	-0.20	-0.01
EXPL	0.03	-0.14	-0.08	-0.05	-0.12	0.14
FACT	-0.17	-0.02	0.03	-0.14	0.14	-0.05
HYPO	0.10	0.10	0.06	0.18	0.13	-0.02
IMAG	0.03	0.02	-0.05	0.11	-0.00	0.13
INTE	-0.07	-0.07	-0.04	0.03	0.14	-0.12
INVE	-0.07	-0.03	-0.15	-0.01	0.18	0.06
LAW	-0.05	0.11	0.01	0.11	-0.07	0.07
PROO	0.15	0.09	-0.07	0.07	0.05	0.17
PUZZ	-0.05	-0.03	0.13	0.16	-0.04	-0.09
QUES	-0.04	0.12	-0.11	-0.17	0.04	0.13
THEO	0.14	-0.08	0.05	-0.16	-0.05	-0.13
CONC	0.19	0.07	0.19	-0.04	0.08	0.18
DISC	-0.21	-0.09	-0.09	-0.11	0.00	-0.19
EVID	0.29	0.16	-0.04	0.11	-0.11	-0.17
EXPE	-0.07	0.21	0.23	-0.00	0.23	0.03
EXPL	-0.19	0.20	-0.22	-0.06	0.14	-0.11
FACT	-0.29	0.04	0.16	0.01	-0.12	0.18
HYPO	0.03	0.07	-0.34	-0.09	-0.14	-0.11
IMAG	0.09	0.17	0.04	-0.04	0.03	0.14
INTE	0.18	-0.21	0.14	0.19	-0.13	0.03
INVE	0.01	-0.30	-0.15	-0.00	-0.20	0.04
LAW	-0.23	-0.12	-0.07	-0.19	0.05	-0.01
PROO	0.18	-0.14	-0.22	0.12	0.11	-0.07
PUZZ	0.04	-0.17	0.14	0.11	0.05	-0.12
QUES	0.02	0.27	-0.02	-0.16	-0.08	0.07
THEO	-0.04	-0.18	0.25	0.16	0.08	0.11

TABLE XLVIII (CONT.)
KRUSKAL SOLUTIONS OF CARROLL SUBGROUPS
SJ9 GRPS 1,2,3; SJ12 GRPS 1,2,3

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.05	-0.13	-0.20	-0.12	-0.06	0.14
DISC	0.13	-0.23	0.02	-0.03	-0.07	-0.20
EVID	0.18	0.22	-0.04	0.00	-0.21	0.14
EXPE	0.24	-0.04	-0.12	-0.21	-0.10	-0.05
EXPL	0.10	0.15	0.25	0.09	-0.19	-0.07
FACT	0.09	0.09	-0.27	-0.01	0.18	0.01
HYPO	-0.16	-0.08	0.11	-0.14	0.14	-0.07
IMAG	0.18	-0.02	0.06	-0.00	-0.03	0.13
INTE	0.09	-0.10	0.22	0.22	-0.02	0.01
INVE	-0.27	0.06	-0.08	0.12	0.02	0.20
LAW	-0.16	0.07	0.19	-0.13	-0.02	-0.09
PROO	-0.18	-0.26	0.06	0.11	0.11	-0.14
PUZZ	-0.03	0.21	0.07	0.02	-0.04	-0.11
QUES	-0.04	-0.14	-0.17	0.16	0.12	-0.02
THEO	-0.11	0.21	-0.11	-0.07	0.17	0.13
CONC	-0.11	-0.07	0.13	-0.06	-0.16	0.16
DISC	0.16	0.05	-0.06	-0.22	-0.05	-0.14
EVID	-0.04	0.19	-0.06	0.09	0.25	0.09
EXPE	-0.03	-0.16	0.03	-0.11	0.09	0.25
EXPL	0.08	0.10	0.16	-0.19	0.18	0.00
FACT	-0.06	-0.10	-0.13	0.19	-0.06	0.06
HYPO	0.07	-0.11	-0.06	0.02	-0.22	0.03
IMAG	-0.03	-0.02	0.07	0.16	0.06	0.04
INTE	0.03	0.03	-0.14	-0.25	-0.05	0.07
INVE	-0.09	0.07	-0.14	-0.05	0.04	-0.29
LAW	-0.14	-0.05	-0.04	0.16	-0.00	-0.15
PROO	0.11	-0.11	0.12	-0.01	-0.23	-0.12
PUZZ	0.12	0.01	-0.03	0.17	-0.09	-0.12
QUES	-0.10	0.08	0.09	-0.02	0.23	-0.12
THEO	0.03	0.11	0.05	0.12	0.00	0.24
CONC	-0.02	-0.13	0.03	0.06	-0.20	0.02
DISC	-0.11	0.03	0.01	0.03	-0.05	0.16
EVID	0.09	0.06	-0.11	-0.04	0.18	-0.10
EXPE	-0.02	0.06	0.14	-0.18	-0.05	0.09
EXPL	-0.08	0.06	-0.08	-0.09	0.13	0.06
FACT	0.11	-0.04	0.07	-0.07	-0.15	-0.06
HYPO	-0.09	-0.06	-0.03	0.06	0.12	0.15
IMAG	-0.00	0.05	0.02	-0.02	0.03	0.01
INTE	0.02	-0.03	0.06	-0.14	-0.00	-0.07
INVE	0.03	0.13	0.02	-0.05	0.02	-0.21
LAW	-0.08	-0.03	0.09	-0.06	-0.06	0.10
PROO	-0.05	-0.07	-0.11	0.18	0.13	-0.02
PUZZ	0.03	-0.03	-0.08	0.04	0.01	-0.07
QUES	0.06	-0.07	0.01	0.12	-0.04	0.06
THEO	0.10	0.06	-0.02	0.15	-0.06	-0.12

TABLE XLVIII (CONT.)
KRUSKAL SOLUTIONS OF CARROLL SUBGROUPS
SD9 GRPS 1,2,3; SD12 GRPS 1,2,3

			DIMENSION			
CONCEPT	1	2	3	1	2	3
CONC	-0.04	-0.27	0.16	-0.10	-0.01	0.25
DISC	0.10	0.09	0.21	0.14	-0.10	0.01
EVID	0.00	0.30	0.00	-0.20	-0.07	0.05
EXPE	0.23	0.01	-0.07	0.10	-0.05	-0.14
EXPL	0.12	-0.29	-0.05	-0.09	-0.14	-0.21
FACT	-0.26	-0.17	0.06	-0.12	0.18	0.10
HYPO	-0.11	0.16	-0.03	-0.08	0.22	0.03
IMAG	0.17	0.19	-0.03	0.00	0.05	-0.22
INTE	0.14	-0.05	-0.25	-0.05	-0.24	-0.01
INVE	-0.24	0.13	0.13	0.12	0.12	0.07
LAW	-0.13	-0.22	-0.19	-0.21	0.02	-0.08
PROO	-0.25	0.07	-0.15	0.31	0.02	-0.03
PUZZ	0.03	0.11	-0.24	0.05	0.23	-0.13
QUES	0.25	-0.05	0.14	0.08	-0.02	0.18
THEO	-0.02	-0.01	0.31	0.05	-0.22	0.13
CONC	-0.20	-0.18	-0.07	0.19	0.21	-0.07
DISC	0.02	0.18	-0.14	0.06	-0.12	-0.15
EVID	0.03	-0.06	-0.24	-0.07	0.04	-0.20
EXPE	0.02	-0.19	-0.01	0.18	0.03	-0.16
EXPL	0.22	-0.13	0.00	-0.12	-0.18	0.03
FACT	-0.10	-0.07	0.22	-0.11	0.28	0.10
HYPO	0.06	-0.13	0.13	0.16	-0.07	0.13
IMAG	-0.14	0.03	-0.13	0.07	-0.24	0.01
INTE	0.16	0.11	-0.09	0.25	-0.10	0.02
INVE	0.15	0.07	0.08	-0.15	-0.07	0.19
LAW	-0.19	0.14	-0.01	-0.20	-0.12	-0.15
PROO	0.09	0.13	0.22	0.05	-0.10	0.26
PUZZ	0.04	-0.08	-0.10	-0.08	0.10	-0.17
QUES	-0.13	0.01	0.07	0.00	0.12	0.13
THEO	-0.05	0.17	0.06	-0.23	0.07	0.02
CONC	-0.34	0.07	0.26	-0.08	-0.12	-0.05
DISC	-0.22	-0.28	0.17	-0.18	-0.16	-0.32
EVID	0.01	-0.36	-0.20	-0.15	0.21	0.27
EXPE	-0.24	-0.07	-0.27	0.08	0.12	-0.25
EXPL	-0.35	0.17	-0.06	-0.03	-0.45	0.11
FACT	0.36	-0.19	-0.10	0.27	0.41	-0.05
HYPO	0.09	-0.27	0.09	0.06	-0.00	0.31
IMAG	0.25	0.31	-0.10	0.22	-0.10	-0.26
INTE	-0.12	-0.17	-0.19	0.34	-0.09	0.07
INVE	0.11	0.10	-0.40	0.15	-0.27	-0.02
LAW	0.01	0.35	0.24	-0.42	0.06	-0.11
PROO	0.12	-0.06	0.32	-0.32	-0.19	0.26
PUZZ	0.35	0.08	0.05	0.22	0.13	0.20
QUES	-0.10	0.34	-0.14	-0.16	0.21	0.02
THEO	0.07	-0.01	0.33	-0.01	0.24	-0.18

TABLE XLIX
CARROLL SOLUTIONS OF CARROLL SUBGROUPS
CAU9 GRPS 1,2,3; CAU12 GRPS 1,2,3

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	0.05	-0.43	0.05	-0.11	0.34	0.28
DISC	-0.15	-0.14	0.30	0.24	0.20	0.13
EVID	0.40	0.28	0.10	0.35	0.27	-0.07
EXPE	-0.15	-0.24	0.09	0.15	-0.27	0.32
EXPL	-0.10	-0.30	0.08	-0.33	0.27	0.17
FACT	0.40	0.20	0.05	0.28	0.30	-0.11
HYPO	-0.23	-0.0	-0.42	-0.26	-0.31	-0.15
IMAG	-0.16	0.24	-0.43	-0.29	-0.10	-0.37
INTE	-0.04	-0.31	-0.16	-0.18	-0.23	-0.42
INVE	-0.01	-0.19	0.26	0.25	-0.32	0.38
LAW	0.33	0.22	0.04	0.26	0.16	-0.25
PROO	0.46	0.25	0.09	0.34	0.32	-0.03
PUZZ	-0.31	0.45	0.20	-0.24	-0.26	0.17
QUES	-0.32	0.08	0.30	-0.29	-0.11	0.28
THEO	-0.16	-0.13	-0.54	-0.17	-0.25	-0.32
CONC	0.15	0.20	-0.12	0.30	-0.23	-0.17
DISC	-0.22	0.39	-0.22	0.04	-0.30	0.01
EVID	0.29	0.32	0.01	0.28	0.41	0.06
EXPE	-0.21	-0.07	0.36	0.00	-0.37	0.30
EXPL	0.28	0.07	-0.14	0.02	-0.10	-0.45
FACT	0.28	0.33	0.05	0.37	0.40	-0.01
HYPO	-0.14	-0.38	-0.27	-0.24	-0.16	0.15
IMAG	-0.41	-0.00	-0.34	-0.36	0.11	-0.18
INTE	0.18	-0.32	-0.17	-0.14	-0.01	-0.50
INVE	-0.23	-0.18	0.41	-0.00	-0.34	0.37
LAW	0.25	0.15	0.04	0.27	0.17	-0.05
PROO	0.33	0.26	0.08	0.37	0.40	0.10
PUZZ	-0.31	-0.24	0.32	-0.35	0.17	0.31
QUES	-0.32	-0.20	0.38	-0.25	-0.07	0.27
THEO	0.06	-0.33	-0.38	-0.31	-0.08	-0.22
CONC	-0.13	-0.28	0.03	0.19	-0.15	-0.38
DISC	-0.24	-0.01	0.15	0.03	-0.20	-0.17
EVID	0.39	0.18	0.36	0.35	-0.15	0.15
EXPE	0.05	-0.04	-0.37	0.02	-0.29	-0.41
EXPL	-0.06	-0.31	-0.09	0.07	0.45	-0.08
FACT	0.32	0.11	0.45	0.33	0.14	0.29
HYPO	0.01	-0.39	-0.26	-0.24	-0.28	-0.12
IMAG	-0.34	0.01	0.21	-0.46	0.07	-0.19
INTE	-0.23	-0.27	-0.04	-0.17	0.38	-0.13
INVE	0.21	0.37	-0.39	0.09	-0.30	-0.19
LAW	0.27	0.18	-0.02	0.19	-0.03	0.39
PROO	0.40	0.16	0.38	0.38	-0.11	0.24
PUZZ	-0.39	0.35	0.01	-0.39	0.28	-0.06
QUES	-0.24	0.31	-0.19	-0.20	0.40	-0.17
THEO	-0.02	-0.37	-0.23	-0.19	-0.21	0.44

TABLE XLIX (CONT.)
CARROLL SOLUTIONS OF CARROLL SUBGROUPS
CAS9 GRPS 1,2,3; CAS12 GRPS 1,2,3

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	0.22	0.17	0.11	0.05	-0.43	0.04
DISC	-0.32	0.14	0.42	-0.15	-0.14	0.30
EVID	0.26	0.23	0.31	0.40	0.28	0.10
EXPE	-0.31	-0.26	0.15	-0.15	-0.24	0.09
EXPL	0.08	0.31	0.07	-0.10	-0.30	0.08
FACT	0.39	0.10	0.27	0.40	0.20	0.05
HYPO	-0.22	0.04	-0.41	-0.23	0.00	-0.42
IMAG	-0.01	-0.13	-0.39	-0.16	0.24	-0.43
INTE	-0.21	-0.25	-0.14	-0.04	-0.31	-0.16
INVE	-0.25	-0.35	-0.04	-0.00	-0.20	0.25
LAW	0.42	0.04	0.00	0.32	0.22	0.04
PROO	0.37	0.12	0.27	0.46	0.26	0.09
PUZZ	-0.15	-0.46	-0.13	-0.31	0.45	0.20
QUES	-0.15	-0.47	-0.12	-0.32	0.08	0.30
THEO	-0.12	0.27	-0.40	-0.16	-0.13	-0.54
CONC	-0.11	0.34	0.28	0.30	-0.23	-0.17
DISC	0.24	0.20	0.13	0.04	-0.30	0.01
EVID	0.35	0.27	-0.07	0.28	0.41	0.06
EXPE	0.15	-0.27	0.32	0.00	-0.37	0.30
EXPL	-0.33	0.27	0.17	0.02	-0.10	-0.45
FACT	0.28	0.30	-0.11	0.37	0.40	0.01
HYPO	-0.26	-0.31	-0.15	-0.24	-0.16	0.15
IMAG	-0.29	-0.10	-0.37	-0.36	0.11	-0.18
INTE	-0.18	-0.23	-0.42	-0.14	-0.01	-0.50
INVE	0.25	-0.32	0.38	-0.00	-0.34	0.37
LAW	0.26	0.16	-0.25	0.27	0.17	-0.05
PROO	0.34	0.32	-0.03	0.37	0.40	0.10
PUZZ	-0.24	-0.26	0.17	-0.35	0.17	0.31
QUES	-0.29	-0.11	0.28	-0.25	-0.07	0.27
THEO	-0.17	-0.25	-0.32	-0.31	-0.08	-0.22
CONC	0.05	0.06	-0.47	0.19	-0.15	-0.38
DISC	-0.21	0.15	-0.06	0.03	-0.20	-0.17
EVID	0.44	0.26	0.18	0.35	-0.15	0.15
EXPE	-0.34	0.23	0.04	0.02	-0.29	-0.41
EXPL	-0.04	-0.08	-0.53	0.07	0.45	-0.08
FACT	0.41	0.25	0.12	0.33	0.14	0.29
HYPO	-0.15	-0.31	-0.07	-0.24	-0.28	-0.12
IMAG	0.01	-0.48	0.25	-0.46	0.07	0.19
INTE	-0.01	-0.30	-0.37	-0.17	0.38	-0.13
INVE	-0.30	0.31	0.12	0.09	-0.30	-0.19
LAW	0.22	0.08	0.08	0.19	-0.03	0.39
PROO	0.43	0.27	0.23	0.38	-0.11	0.24
PUZZ	-0.18	-0.03	0.32	-0.39	0.28	-0.06
QUES	-0.29	0.02	0.24	-0.20	0.40	-0.17
THEO	-0.05	-0.44	-0.07	-0.19	-0.21	0.44

TABLE XLIX (CONT.)
CARROLL SOLUTIONS OF CARROLL SUBGROUPS
SJ9 GRPS 1,2,3; SJ12 GRPS 1,2,3

			DIMENSION			
CONCEPT	1	2	3	1	2	3
CONC	-0.25	0.26	0.16	0.20	0.13	0.18
DISC	-0.15	-0.10	0.25	0.25	-0.37	-0.12
EVID	-0.17	0.11	0.32	0.27	0.17	-0.00
EXPE	0.44	0.01	-0.07	0.04	-0.18	-0.35
EXPL	-0.18	0.24	0.22	0.12	-0.00	0.22
FACT	-0.18	0.25	0.27	0.31	0.34	0.12
HYPO	0.05	-0.41	-0.30	-0.26	-0.31	0.12
IMAG	-0.12	-0.49	-0.30	-0.39	-0.31	0.16
INTE	-0.11	0.32	-0.45	-0.15	-0.22	0.39
INVE	0.32	0.05	-0.09	0.14	-0.09	-0.39
LAW	-0.05	0.28	0.24	0.12	0.57	0.22
PROO	-0.18	0.18	0.33	0.33	0.16	0.06
PUZZ	0.44	-0.27	-0.14	-0.38	0.09	-0.35
QUES	0.42	-0.24	-0.26	-0.31	0.20	-0.46
THEO	-0.30	-0.19	-0.19	-0.30	-0.16	0.20
CONC	0.28	0.10	0.17	0.27	0.14	-0.21
DISC	0.04	0.26	0.41	0.25	-0.20	0.23
EVID	0.19	0.17	0.08	0.20	0.28	-0.12
EXPE	-0.10	0.34	-0.01	-0.02	-0.11	0.39
EXPL	0.18	0.01	0.22	0.24	-0.10	-0.15
FACT	0.18	0.28	0.11	0.28	0.37	-0.23
HYPO	-0.19	-0.34	-0.28	-0.39	-0.32	-0.05
IMAG	-0.41	-0.56	0.28	-0.31	-0.48	-0.14
INTE	0.16	-0.14	0.25	0.19	-0.20	-0.34
INVE	-0.08	0.18	-0.07	-0.01	0.05	0.41
LAW	0.33	-0.20	-0.24	0.05	0.45	-0.25
PROO	0.23	0.22	0.18	0.25	0.25	-0.10
PUZZ	-0.52	0.01	-0.38	-0.34	-0.23	0.38
QUES	-0.37	0.02	-0.42	-0.30	-0.00	0.35
THEO	0.10	-0.35	-0.31	-0.38	-0.10	-0.16
CONC	0.16	0.17	-0.06	0.18	0.18	-0.24
DISC	0.05	0.38	0.29	0.25	-0.17	-0.04
EVID	0.24	0.19	-0.21	0.29	0.05	-0.01
EXPE	0.08	0.05	0.26	-0.07	-0.05	-0.12
EXPL	0.03	-0.13	-0.09	-0.04	0.13	-0.25
FACT	0.34	0.09	-0.22	0.34	0.13	0.05
HYPO	-0.35	0.09	0.07	-0.14	0.11	-0.31
IMAG	-0.53	-0.53	-0.05	-0.46	-0.59	0.28
INTE	-0.32	0.00	-0.27	-0.24	0.06	-0.30
INVE	0.24	0.04	0.25	-0.00	0.21	0.17
LAW	0.21	0.06	-0.46	0.32	0.04	0.28
PROO	0.26	0.24	-0.08	0.30	0.01	-0.03
PUZZ	-0.21	-0.39	0.52	-0.34	-0.61	0.37
QUES	0.07	-0.47	0.25	-0.33	0.25	0.49
THEO	-0.27	0.20	-0.19	-0.05	0.24	-0.33

TABLE XLII (CONT.)
CARROLL SOLUTIONS OF CARROLL SUBGROUPS
SD9 GRPS 1,2,3; SD12 GRPS 1,2,3

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.20	0.03	0.22	0.08	0.19	-0.27
DISC	0.36	0.31	-0.27	0.23	-0.14	-0.53
EVID	0.06	0.31	-0.16	0.44	0.06	0.02
EXPE	0.33	0.19	-0.30	-0.07	-0.23	-0.07
EXPL	-0.16	0.01	0.18	0.21	0.36	-0.04
FACT	0.24	0.24	0.31	0.18	0.45	-0.27
HYPO	-0.34	-0.40	0.27	-0.20	-0.35	0.29
IMAG	-0.23	-0.44	0.28	0.06	-0.16	0.15
INTE	-0.29	-0.25	0.15	-0.05	-0.18	0.27
INVE	0.33	-0.23	-0.26	-0.41	-0.06	0.13
LAW	0.11	-0.07	-0.18	0.06	0.24	-0.25
PROO	0.31	0.31	0.18	0.38	0.35	-0.26
PUZZ	0.05	0.30	-0.56	-0.23	-0.22	0.31
QUES	-0.31	-0.21	-0.01	-0.44	0.05	0.25
THEO	-0.25	-0.11	0.15	-0.24	-0.36	0.27
CONC	0.04	0.15	-0.18	0.14	0.14	-0.05
DISC	0.20	0.03	-0.32	0.14	0.05	0.03
EVID	0.26	0.17	-0.27	0.34	0.28	0.42
EXPE	0.27	0.25	-0.05	-0.14	0.14	0.31
EXPL	0.07	0.04	-0.14	0.08	0.37	-0.41
FACT	0.11	0.02	-0.24	0.26	0.27	0.34
HYPO	-0.39	-0.00	0.21	-0.08	-0.48	-0.20
IMAG	-0.32	-0.30	0.0	-0.21	-0.30	-0.25
INTE	-0.33	0.13	-0.10	-0.07	0.12	-0.04
INVE	0.29	0.24	0.40	-0.05	-0.03	0.20
LAW	0.32	0.09	-0.12	0.03	-0.00	0.12
PROO	0.24	0.08	-0.25	0.46	0.25	0.28
PUZZ	-0.23	-0.73	0.32	-0.44	-0.40	-0.19
QUES	-0.28	-0.37	0.51	-0.54	-0.07	-0.27
THEO	-0.25	0.19	0.24	0.07	-0.34	-0.30
CONC	0.22	-0.15	0.38	-0.41	0.10	-0.59
DISC	0.05	0.27	0.20	0.22	0.20	0.20
EVID	0.37	0.10	0.11	0.11	0.14	0.32
EXPE	0.04	0.35	0.07	0.31	0.19	0.43
EXPL	-0.06	0.26	0.11	-0.27	0.09	-0.07
FACT	0.33	0.07	-0.11	-0.14	0.23	-0.01
HYPO	-0.44	-0.35	-0.40	-0.10	-0.49	-0.23
IMAG	-0.01	-0.10	-0.21	-0.02	-0.35	0.26
INTE	-0.33	-0.55	-0.06	-0.07	-0.02	-0.09
INVE	-0.06	0.10	-0.13	0.32	0.36	0.02
LAW	0.18	0.22	0.08	0.11	-0.01	-0.04
PROO	0.37	0.06	0.27	-0.16	0.26	0.16
PUZZ	-0.19	0.24	0.42	0.45	0.04	0.12
QUES	-0.03	-0.30	-0.34	0.11	-0.43	-0.36
THEO	-0.43	-0.22	-0.40	-0.46	-0.29	-0.14

TABLE L
CARROLL SOLUTIONS OF TUCKER SUBGROUPS
CAU9 GROUPS 1,2,3,4; CAU12 GROUPS 1,2

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.21	0.21	0.15	0.12	0.20	0.12
DISC	-0.13	0.18	-0.19	-0.03	0.26	-0.43
EVID	0.53	0.21	0.09	0.20	-0.06	-0.28
EXPE	-0.07	-0.04	-0.62	0.19	0.29	-0.22
EXPL	-0.26	0.30	0.26	0.02	0.11	0.25
FACT	0.43	0.19	0.11	0.27	-0.48	-0.19
HYPO	-0.09	-0.49	0.17	-0.11	0.24	0.28
IMAG	-0.09	-0.20	0.11	-0.64	-0.19	-0.01
INTE	-0.13	-0.21	0.05	-0.52	0.01	-0.04
INVE	-0.08	0.01	-0.60	0.15	0.24	-0.31
LAW	0.14	-0.11	0.06	-0.05	-0.48	0.10
PROO	0.48	0.26	0.07	0.25	-0.36	-0.22
PUZZ	-0.21	0.09	0.18	0.12	-0.07	0.46
QUES	-0.26	0.16	0.02	0.18	0.23	0.36
THEO	-0.04	-0.55	0.14	-0.12	0.07	0.13
CONC	-0.32	-0.18	-0.10	-0.02	-0.35	-0.40
DISC	-0.11	-0.06	-0.48	0.40	0.16	-0.58
EVID	-0.25	0.38	0.12	0.30	-0.29	0.03
EXPE	0.17	-0.06	-0.52	0.12	0.32	0.17
EXPL	-0.30	-0.07	0.07	-0.24	-0.07	0.17
FACT	-0.21	0.38	0.17	0.19	-0.45	0.20
HYPO	0.10	-0.39	0.22	-0.29	0.27	0.10
IMAG	0.25	-0.28	0.21	-0.31	0.05	-0.08
INTE	-0.25	-0.30	0.11	-0.30	0.08	-0.33
INVE	0.26	0.02	-0.50	0.25	0.20	0.34
LAW	0.07	0.45	0.17	0.26	-0.21	0.17
PROO	-0.22	0.34	0.15	0.30	-0.37	-0.16
PUZZ	0.46	-0.10	0.16	-0.25	0.19	0.21
QUES	0.44	-0.14	0.11	-0.24	0.18	0.24
THEO	-0.08	0.0	0.11	-0.18	0.30	-0.08
CONC	0.11	-0.39	-0.25	-0.25	-0.26	-0.27
DISC	0.05	-0.10	-0.45	0.07	0.36	-0.25
EVID	0.24	-0.15	0.23	0.35	-0.17	-0.11
EXPE	0.21	0.32	-0.17	-0.09	-0.09	-0.42
EXPL	-0.10	-0.25	-0.37	-0.17	-0.17	0.26
FACT	0.20	-0.28	0.43	0.35	-0.18	0.01
HYPO	-0.09	0.30	-0.06	-0.27	-0.20	-0.26
IMAG	-0.48	0.11	0.15	-0.26	0.08	0.20
INTE	-0.46	-0.13	-0.11	-0.26	-0.19	0.17
INVE	0.23	0.34	-0.12	0.06	0.49	-0.36
LAW	0.10	-0.27	0.38	0.40	-0.05	0.28
PROO	0.26	-0.23	0.34	0.28	-0.19	-0.10
PUZZ	0.10	0.32	0.04	-0.19	0.54	0.40
QUES	0.11	0.32	-0.11	-0.29	0.16	0.25
THEO	-0.48	0.07	0.07	0.27	-0.13	0.19

TABLE L (CONT.)
CARROLL SOLUTIONS OF TUCKER SUBGROUPS
CAU12 GROUPS 3,4; CAS9 GROUPS 1,2,3,4

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.15	-0.37	-0.24	-0.03	-0.23	-0.03
DISC	-0.0	-0.24	0.34	-0.17	0.13	-0.14
EVID	-0.35	0.19	-0.13	0.45	0.26	0.12
EXPE	0.01	-0.24	0.00	-0.15	0.15	-0.52
EXPL	0.03	-0.10	-0.42	0.06	-0.53	0.11
FACT	-0.35	0.36	0.05	0.49	0.13	0.08
HYPO	0.18	-0.28	-0.07	-0.14	-0.17	-0.48
IMAG	0.43	0.54	-0.16	-0.19	-0.01	0.21
INTE	0.21	-0.05	-0.31	-0.05	-0.50	0.20
INVE	-0.05	0.13	0.39	-0.22	0.31	-0.05
LAW	-0.33	0.28	0.06	-0.01	0.12	0.22
PROO	-0.40	0.17	-0.17	0.51	0.26	0.10
PUZZ	0.31	-0.04	0.45	-0.25	0.18	0.30
QUES	0.19	-0.10	0.31	-0.25	0.11	0.26
THEO	0.27	-0.24	-0.11	-0.06	-0.21	-0.37
CONC	-0.01	-0.16	0.05	-0.19	0.03	-0.20
DISC	-0.23	-0.38	-0.05	-0.34	-0.36	0.02
EVID	-0.31	0.31	0.38	-0.31	0.27	0.46
EXPE	-0.08	-0.50	0.13	-0.32	-0.14	-0.33
EXPL	-0.10	0.06	-0.09	0.10	0.32	-0.18
FACT	-0.30	0.28	0.17	-0.11	0.23	0.20
HYPO	0.30	0.11	-0.40	0.31	0.17	-0.17
IMAG	0.12	0.05	-0.23	0.36	-0.21	0.14
INTE	0.06	0.13	-0.27	0.15	0.20	-0.16
INVE	-0.01	-0.48	0.10	-0.21	-0.24	-0.40
LAW	-0.20	0.21	0.03	0.09	-0.40	0.32
PROO	-0.22	0.27	0.38	-0.32	0.34	0.43
PUZZ	0.54	0.02	0.18	0.29	-0.30	0.09
QUES	0.51	-0.04	0.15	0.18	-0.17	-0.19
THEO	-0.07	0.13	-0.54	0.33	0.24	-0.02
CONC	-0.10	0.12	0.28	-0.27	-0.34	-0.19
DISC	0.15	0.30	-0.13	-0.04	-0.07	-0.21
EVID	0.42	-0.34	-0.18	-0.26	0.39	-0.09
EXPE	0.09	0.42	-0.29	0.22	-0.02	-0.24
EXPL	-0.18	0.08	0.41	-0.28	-0.31	-0.11
FACT	0.40	-0.34	0.09	-0.27	0.41	-0.04
HYPO	-0.24	0.01	0.22	0.06	-0.25	0.42
IMAG	-0.33	-0.16	-0.52	0.30	-0.04	0.45
INTE	-0.19	0.09	0.15	-0.13	-0.27	-0.12
INVE	0.19	0.39	-0.17	0.29	-0.05	-0.22
LAW	0.12	-0.28	0.02	-0.17	0.30	0.28
PROO	0.39	-0.40	0.03	-0.28	0.43	-0.09
PUZZ	-0.36	-0.14	-0.37	0.44	0.04	-0.14
QUES	-0.21	0.16	0.18	0.40	-0.03	-0.22
THEO	-0.16	0.09	0.28	-0.01	-0.20	0.50

TABLE L (CONT.)
CARROLL SOLUTIONS OF TUCKER SUBGROUPS
CAS12 GROUPS 1,2,3,4; SJ9 GROUPS 1,2

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	0.05	-0.31	0.19	0.25	-0.21	-0.00
DISC	0.23	-0.05	0.20	0.02	-0.29	0.06
EVID	-0.45	0.27	0.18	-0.43	-0.04	0.34
EXPE	0.19	-0.15	0.24	0.17	-0.48	0.04
EXPL	-0.03	-0.27	0.14	0.03	0.34	-0.43
FACT	-0.47	0.22	0.14	-0.38	0.11	0.08
HYPO	0.26	0.09	-0.19	0.25	-0.34	-0.38
IMAG	0.05	0.10	-0.72	0.36	0.33	0.28
INTE	-0.12	-0.35	-0.36	0.18	0.31	0.19
INVE	0.31	0.14	0.19	-0.12	-0.28	0.03
LAW	0.04	0.41	-0.08	-0.39	0.14	0.01
PROO	-0.44	0.32	0.20	-0.28	-0.09	0.36
PUZZ	-0.08	-0.36	-0.14	0.29	0.19	0.14
QUES	0.18	-0.27	0.01	0.12	0.16	-0.28
THEO	0.27	0.20	-0.01	-0.07	0.15	-0.45
CONC	-0.14	-0.24	-0.06	-0.26	0.13	-0.29
DISC	0.02	-0.18	-0.15	-0.04	0.00	-0.45
EVID	-0.36	0.31	0.18	-0.32	-0.00	0.27
EXPE	0.40	0.09	0.38	0.06	-0.38	-0.31
EXPL	-0.02	0.00	-0.34	-0.01	0.41	-0.34
FACT	-0.33	0.38	0.03	-0.36	0.05	0.38
HYPO	0.49	0.18	0.07	0.24	-0.18	-0.07
IMAG	-0.02	-0.30	-0.35	0.32	0.20	0.15
INTE	0.08	-0.16	-0.38	0.19	0.48	-0.02
INVE	0.10	-0.13	0.46	0.05	-0.47	-0.06
LAW	-0.08	0.09	-0.01	-0.28	0.08	0.27
PROO	-0.41	0.39	0.05	-0.42	-0.00	0.22
PUZZ	-0.09	-0.44	0.19	0.31	-0.25	0.11
QUES	-0.01	-0.26	0.23	0.22	-0.24	-0.16
THEO	0.38	0.28	-0.31	0.32	0.17	0.32
CONC	-0.25	-0.25	0.42	0.30	-0.34	-0.29
DISC	-0.00	-0.06	0.40	0.23	-0.08	0.01
EVID	-0.16	-0.21	-0.06	0.26	0.26	-0.09
EXPE	0.03	0.39	-0.20	0.18	-0.31	0.31
EXPL	-0.24	-0.22	0.15	-0.04	-0.03	-0.31
FACT	-0.29	-0.20	-0.38	0.23	0.36	-0.18
HYPO	0.41	0.08	0.13	-0.37	-0.15	0.05
IMAG	0.50	-0.14	0.03	-0.44	-0.01	-0.13
INTE	-0.13	-0.10	0.18	-0.14	-0.31	-0.34
INVE	-0.04	0.30	0.02	0.12	-0.30	0.33
LAW	-0.30	-0.06	-0.25	0.12	0.48	-0.15
PROO	-0.25	-0.16	-0.40	0.28	0.36	-0.01
PUZZ	0.20	0.48	0.32	-0.35	-0.09	0.52
QUES	0.22	0.44	-0.12	-0.36	0.12	0.38
THEO	0.30	-0.29	-0.23	-0.03	0.04	-0.09

TABLE L (CONT.)
CARROLL SOLUTIONS OF TUCKER SUBGROUPS
SJ9 GROUPS 3,4; SJ12 GROUPS 1,2,3,4

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.18	0.23	0.01	-0.30	0.18	0.10
DISC	-0.16	0.15	-0.10	-0.38	-0.15	-0.00
EVID	-0.31	0.15	-0.05	-0.17	0.30	-0.18
EXPE	0.15	-0.00	-0.36	-0.07	-0.33	-0.26
EXPL	-0.26	0.14	0.05	-0.22	-0.00	0.09
FACT	-0.38	0.05	0.01	-0.21	0.30	-0.27
HYPO	0.31	-0.11	0.32	0.23	-0.22	0.27
IMAG	0.22	-0.54	0.43	0.35	-0.17	0.45
INTE	0.34	0.31	0.10	-0.07	0.04	0.55
INVE	0.11	0.02	-0.45	0.00	-0.21	-0.28
LAW	-0.26	0.12	0.28	0.08	0.46	-0.22
PROO	-0.30	0.25	-0.02	-0.28	0.27	-0.15
PUZZ	0.21	-0.56	-0.21	0.38	-0.37	-0.17
QUES	0.30	-0.28	-0.34	0.33	-0.28	-0.12
THEO	0.22	0.08	0.35	0.34	0.18	0.20
CONC	0.28	-0.03	-0.11	-0.15	0.24	-0.26
DISC	-0.06	-0.06	-0.22	-0.18	0.43	-0.05
EVID	0.24	0.12	0.05	-0.35	-0.07	-0.02
EXPE	-0.15	0.32	0.39	0.20	0.13	-0.09
EXPL	0.16	0.20	-0.31	-0.11	-0.10	-0.29
FACT	0.32	0.12	-0.18	-0.35	-0.35	-0.13
HYPO	-0.31	0.52	-0.10	0.28	0.15	0.14
IMAG	-0.48	-0.17	-0.38	0.45	0.07	0.32
INTE	0.01	-0.15	-0.29	0.10	0.21	-0.33
INVE	-0.01	-0.15	0.50	-0.18	0.34	0.23
LAW	0.36	-0.41	0.14	-0.20	-0.51	-0.00
PROO	0.28	0.06	0.07	-0.25	-0.29	-0.16
PUZZ	-0.37	-0.39	0.18	0.23	0.06	0.55
QUES	-0.14	-0.27	0.32	0.10	-0.05	0.37
THEO	-0.14	0.28	-0.06	0.40	-0.26	-0.28
CONC	-0.24	0.20	0.08	-0.20	0.27	-0.16
DISC	0.0	-0.13	0.26	-0.09	-0.01	-0.17
EVID	-0.19	0.11	0.31	-0.20	0.15	-0.14
EXPE	0.18	-0.04	0.02	0.19	0.01	0.06
EXPL	-0.17	0.08	-0.04	-0.08	0.31	0.07
FACT	-0.36	0.10	0.23	-0.46	0.16	-0.13
HYPO	0.22	0.19	-0.23	0.04	-0.55	-0.15
IMAG	0.18	-0.53	-0.50	0.32	-0.27	0.11
INTE	-0.26	-0.03	-0.40	0.33	0.30	-0.24
INVE	0.31	0.18	0.26	0.21	0.11	-0.06
LAW	-0.25	-0.01	0.24	-0.43	0.13	0.20
PROO	-0.27	0.10	0.27	-0.27	0.22	-0.16
PUZZ	0.44	-0.66	-0.08	0.27	-0.29	0.45
QUES	0.38	0.08	-0.13	0.16	-0.25	0.65
THEO	0.03	0.34	-0.29	0.22	-0.29	-0.33

TABLE L (CONT.)

CARROLL SOLUTIONS OF TUCKER SUBGROUPS
SD9 GROUPS 1,2,3,4; SD12 GROUPS 1,2

	DIMENSION					
CONCEPT	1	2	3	1	2	3
CONC	-0.17	-0.43	0.11	0.00	-0.18	0.00
DISC	-0.34	0.30	-0.10	0.07	-0.50	-0.25
EVID	-0.26	0.22	0.19	0.56	-0.07	-0.06
EXPE	-0.05	0.31	0.46	0.07	0.04	0.38
EXPL	-0.05	-0.18	-0.01	0.06	-0.01	-0.23
FACT	-0.26	-0.43	-0.09	0.29	-0.33	-0.26
HYPO	0.44	0.19	-0.27	-0.19	0.33	0.45
IMAG	0.10	0.02	-0.40	-0.12	0.17	-0.12
INTE	0.13	-0.27	-0.28	-0.18	0.24	0.51
INVE	0.10	[illegible]	0.44	-0.05	0.08	0.01
LAW	-0.33	0.19	0.18	0.05	-0.30	-0.19
PROO	-0.27	0.01	0.12	0.41	-0.30	-0.02
PUZZ	0.32	0.28	-0.11	-0.23	0.31	-0.35
QUES	0.39	-0.26	0.14	-0.47	0.22	-0.05
THEO	0.24	-0.17	-0.37	-0.26	0.29	0.19
CONC	0.10	-0.19	-0.24	-0.14	-0.23	-0.19
DISC	-0.37	-0.26	0.34	-0.16	-0.10	0.29
EVID	-0.20	-0.25	0.05	-0.21	-0.12	-0.11
EXPE	-0.32	0.06	-0.06	-0.16	0.06	-0.37
EXPL	0.17	-0.31	-0.12	-0.08	-0.27	0.41
FACT	-0.17	-0.19	-0.25	-0.10	-0.37	0.11
HYPO	0.39	0.22	-0.34	0.14	0.42	-0.19
IMAG	0.37	-0.12	-0.08	0.19	0.11	0.40
INTE	0.32	0.07	-0.09	-0.11	0.31	-0.15
INVE	-0.11	0.51	0.42	-0.14	0.03	-0.29
LAW	0.06	-0.03	0.46	-0.16	-0.20	0.14
PROO	-0.37	-0.34	-0.01	-0.11	-0.36	-0.16
PUZZ	-0.22	0.17	0.02	0.77	0.18	-0.04
QUES	0.21	0.38	0.27	0.38	0.07	0.38
THEO	0.13	0.29	-0.38	-0.10	0.47	-0.22
CONC	-0.45	-0.13	0.43	-0.24	-0.03	0.22
DISC	0.21	-0.25	0.07	0.09	0.22	-0.36
EVID	0.35	-0.31	-0.25	-0.30	0.21	-0.31
EXPE	0.33	-0.16	-0.51	0.00	0.28	-0.17
EXPL	-0.20	-0.18	0.24	-0.33	-0.38	-0.36
FACT	-0.05	-0.14	0.05	-0.32	0.33	0.24
HYPO	-0.20	0.54	0.10	0.39	-0.03	0.26
IMAG	0.08	0.06	-0.34	0.31	-0.33	0.09
INTE	-0.05	0.33	-0.29	-0.23	-0.31	0.40
INVE	0.28	-0.05	0.25	0.02	0.21	-0.27
LAW	0.03	-0.16	0.03	0.01	0.19	-0.03
PROO	-0.08	-0.25	0.07	-0.27	0.28	-0.29
PUZZ	0.34	0.45	0.20	0.36	-0.02	0.12
QUES	-0.12	0.21	0.19	0.27	-0.20	0.19
THEO	-0.46	0.05	-0.25	0.24	-0.41	0.26

TABLE L (CONT.)
CARROLL SOLUTIONS OF TUCKER SUBGROUPS
SD12 GROUPS 3,4

CONCEPT	DIMENSION 1	2	3	1	2	3
CONC	-0.26	-0.17	0.02	-0.05	0.40	0.36
DISC	-0.11	0.19	-0.43	-0.03	0.23	-0.31
EVID	-0.32	0.23	-0.09	0.65	0.16	0.09
EXPE	-0.07	0.36	0.33	0.12	0.12	-0.28
EXPL	0.02	0.24	-0.02	-0.14	0.11	0.02
FACT	-0.33	0.28	-0.13	0.22	-0.20	-0.18
HYPO	0.44	-0.34	-0.18	-0.27	-0.44	0.41
IMAG	0.17	-0.16	-0.06	-0.14	-0.11	0.33
INTE	0.32	-0.17	0.00	-0.19	-0.13	-0.03
INVE	0.11	0.38	0.12	0.00	-0.12	-0.35
LAW	-0.20	0.05	-0.20	-0.02	0.15	-0.01
PROO	-0.32	0.01	0.05	0.47	0.20	-0.18
PUZZ	0.03	-0.43	-0.19	-0.26	0.36	-0.33
QUES	0.06	-0.17	0.74	-0.19	-0.32	0.17
THEO	0.46	-0.30	0.04	-0.18	-0.41	0.29